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THE

SCIENTIFIC PROCEEDINGS

OF THE

ROYAL DUBLIN SOCIETY.

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New Series.

VOLUME III.

DUBLIN:
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I.—ON A NEW FORM OF GHOST MICROMETER FOR USE WITH ASTRONOMICAL TELESCOPES, BY CHAS. E. BURTON, F.R.A.S., AND HOWARD GRUBB, F.R.A.S. PLATES 1, 2, 3, AND 4.

[Read, November 15th, 1880.]

BEFORE describing the special and novel form of micrometer we have to introduce to your notice this evening it may be well to mention very briefly the various existing forms which this instrument usually assumes, and note the special points in which it fails to fulfil its requirements with as much satisfaction as desired.

The ordinary micrometer in general use consists essentially of a metallic box attached to the draw-tube of the telescope, in which are one or two frames or forked-shaped pieces sliding in carefully-planed grooves, actuated by a fine screw and micrometer head, and carrying spider's webs or other very fine lines. These lines are so placed as to be exactly in the focal plane of the objective. When, therefore, the eye-piece is focussed on any image formed by the objective of the telescope it is also in focus for the wires or webs of the micrometer. According as the micrometer has one or two movable wire-frames and screws it is termed a unifilar or bifilar. In order to see these fine lines at night it is almost always necessary to illuminate them in some way. There are two distinct methods of doing this, viz.:—

1st. By throwing a little false light into the field, in which

case the lines appear black on a faintly illuminated ground, this is called the Bright Field Illumination.

2nd. By throwing light on the wires in such a direction that none of the beam can by possibility enter the eye-piece, in which case the lines appear luminous on a dark ground. This is called the dark field or the Bright Line Illumination.

The first, which can be used for all stars but those whose visibility is so slight as to be interfered with by the necessary amount of false light required to render the webs visible is more specially suited for faint stars and nebulæ, but can be used for any class of object.

The optical arrangements by which the Bright Field Illumination is obtained are too obvious to require detailed description. Sometimes a small, diagonal mirror is used, placed centrally in the tube and illuminated by a lamp hung in gimbals so as to preserve its verticality; sometimes an elliptical diagonal mirror, with an elliptical hole sufficiently large to admit the pencil of light from the objective. But this is a matter of extreme simplicity, requiring no special care further than that the illumination should be as far as possible symmetrical and not one-sided, a condition easy to fulfil in this case.

The optical arrangements, however, for producing the "bright light" in "dark field" illumination are not so simple, and as this is a matter in which no thoroughly satisfactory result has yet been attained, we purpose describing the various arrangements at present in use somewhat more particularly.

One of the most common arrangements in use is to have four lamps attached to the micrometer-box, directing beams of light at an angle of about 45° on the wires. This plan has several disadvantages. The angle of 45° is about the largest that can well be used, and this is not sufficiently great to prevent some stray light from impinging on the field lens of the eye-piece, and though it does not actually enter the eye as a beam of light, it renders the field lens slightly luminous and destroys the blackness of the field which is essential to this class of illumination. Another disadvantage is the extreme inconvenience of having lamps attached to a micrometer close to the observer's eye. These lamps cannot well be hung in universal joints, consequently every time the telescope is turned, or micrometer revolved into different positions, the lamps must be re-arranged, and if this be not done

constantly and carefully, the lamps, not being vertical, allow the oil to escape over the micrometer and person of the observer in a highly objectionable manner. So great is this nuisance that almost invariably observers try and work with one lamp; but this is essentially bad, giving a one-sided illumination to the wires, and thereby causing serious errors of estimation.

The next plan we would notice is that of surrounding the system of wires by a thin, translucent substance such as a very thin tube of ivory, and rendering this luminous by light thrown in any direction. This plan answers tolerably well for a faint illumination; but it is difficult to obtain sufficient brilliancy for any save faint objects, and if any considerable brilliancy is obtained it is almost impossible to prevent the field lens of the eye-piece becoming luminous and destroying the blackness of the field. As before stated, however, it can be made to answer for faint objects, and this plan has occasionally been used by one of the authors of this paper (Mr. Grubb), when other plans were not conveniently adaptable, as in the case of the Dunsink Refractor.

A third plan is that for which arrangements have been made in the Vienna Telescope, but which, so far as it goes, has frequently been used before (see Plate 1, fig. 1). Four prisms or reflectors are placed in the telescope tube opposite the Dec. axis, which prisms direct the light down through four tubes placed in the interior of the main telescope tube. In the diagram (Plate 1, fig. 1), are two of these four prisms (the other two could not be shown with convenience). These four beams of light are then received on four small reflectors, two of which are shown in diagram. (r. r.) These reflectors surround the wire plate, and the light reflected from these mirrors passes across the wires at such a considerable angle as prevents any danger of the field lens being illuminated or the blackness of the field injured.

A fourth plan is shown in Plate 1, figure 2, and is that adopted generally by one of the authors (Mr. Grubb) for his smaller instruments.

A prism, P, on outside of telescope tube receives light from a swinging lamp and reflects it down through a small tube attached to outside of main telescope tube, where it is thrown on a reflector, R. This reflector, R, is carried on the end of a T tube which is capable of revolution round the tube which carries the micro-

meter. The tube which carries the micrometer is cut up with slots, so that it forms a "cage" into which the beam of light can enter at any part of its periphery, excepting only for the slight obstruction of the bars of the cage. Inside this cage is another piece of tube carrying a diagonal reflector, m, m, with an elliptical hole large enough to allow the whole pencil of rays for objective to pass. By a simple mechanical arrangement the inside tube carrying the diagonal reflector, m, m, and the outside tube carrying the reflector, R, are made to revolve simultaneously by the action of one pinion head. Thus, the reflector, R, and the reflector, m, m, can always be kept in such a position as to receive the light from the prism, P, which is thus reflected from R to m, m, and from m, m, to the four reflectors, r, r, surrounding the wire frame, as in Plate 1, figure 2.

A fifth plan is shown, Plate II., figure 3, as used by Mr. Grubb for some of his larger instruments. In this plan the lamp is hung at end of Dec. axis, and sends a beam through that axis. At a certain point of that axis is placed a low power condensing lens, b, having a small opaque disc, o, attached to its centre. In the telescope tube opposite Dec. axis is fixed a prism, R, ground on one of its faces, concave, and having a convex lens cemented on to it thus forming an achromatic lens as well as a reflector. This reflector directs the rays in a diagonal direction down to the draw tube of the telescope, and when the curves of this prism and lens are properly proportioned it forms an image of the condenser, b, and its opaque spot, o, on the upper end of the draw tube, P P. The image is, therefore, of the form of a ring of light. At P P is placed a portion of an excentric lens, with a hole in the middle to allow the cone of rays from objective to pass. This lens serves a double purpose. It alters the direction of the beam so that it may travel down between two concentric tubes to the little prisms, p p, round the wires, and it also condenses the beam so that none need be lost, but all be caught by those small prisms, p p. From these prisms, p p, the light is sent across the wires as in the former cases.

But few objections can be urged against the last three systems here described, except that they are all, more or less, difficult to [illegible] when adjusted, and, at the best, only afford lumination for the fainter class of objects.

The attention of one of the authors of this paper (Mr. Grubb) was called to the subject lately, partly by the necessity of devising some special instruments for special work, but more particularly by a letter from Mr. S. W. Burnham, of Chicago, the well-known and successful observer of double stars. At the same time the attention of the other author (Mr. Burton) was called to the same subject by perusal of Prof. Kaiser's paper, referred to further on, and on mentioning the special points of the matter to Mr. Grubb, Mr. Grubb was enabled to place in Mr. Burton's hands a model of a micrometer, which he had devised to fulfil some of Mr. Burnham's conditions, made without special reference to the points raised in Prof. Kaiser's paper, but which did, nevertheless, meet them. On trial of this model micrometer Mr. Burton found it to work admirably, and since then the two authors, working together, have so far perfected the instrument which you see, bringing it into a convenient and workable form.

The following short notice, which formed part of a paper read at a recent meeting of the Royal Astronomical Society, will help to convey an idea of the special point of the matter.

It is well known that the ordinary wire micrometer is unsuitable for the direct measurement of two classes of objects, namely, planetary discs and double stars near the limit of separability for the object glass employed.

The difficulties attendant on its use in the cases above mentioned are briefly these—(*a*) (1.) on bringing a material line in contact with the image of a luminous object of sensible magnitude, diffracted light appears on the side of the wire furthest from the image to be measured; and (2nd), if a wire be placed on the image of a star, that image becomes elongated in a direction perpendicular to the wire: defect (1) renders it extremely difficult to ascertain when a micrometer wire is accurately in contact with the limb of a planet.—(*b*) by reason of the interval between components of extremely close doubles becoming filled with light when the wires are placed on the components, it is impossible to obtain direct measures of such objects with the required certainty.

The difficulties above indicated have been treated very completely by Professor Kaiser, in volume 3 of the Leyden Observations, pp. 104-5, where he refers with approval to a proposal by Lamont

(Jahrbuch der K.S. bei München; seite 187) to employ ghost lines for such measurements, and by the Rev. W. R. Dawes, in Mem. Royal Astronomical Society, vol. 35, pp. 153 and 161.

The suggestions of Professor Kaiser seem never to have been carried into effect.

In the proceedings of the Vienna Academy of Sciences for 1856, vol. XX., page 253, H. Karl v. Littrow describes a mode of forming a "ghost" of a system of lines, applicable and actually applied to a meridional telescope. In this instrument the "ghost" lines are interrupted at or near their centres, by the interposition of an opaque bar, and the star is caused to traverse the series of blank spaces thus formed.

It does not appear, however, that any attempt was made to adapt this to a position micrometer of an equatorial instrument.

An instrument somewhat resembling that of Dr. Littrow, and designed for use as a position micrometer was devised by Mr. G. P. Bidder, and is described by him in the Monthly Notices, Roy. Astr. Soc., for June, 1874. In this form of "ghost" micrometer, the image of the lines is formed by a unilateral oblique pencil of rays, and it would, probably, be difficult to avoid loss of definition, due to dispersion by the lenses of the eyepiece, as well as to preserve an invariable scale value, on account of the want of a sufficiently rigid connexion between the several parts of the instrument. Any movement of the second prism of the optical train, as proposed for the purpose of transferring the system of "ghost" lines to any part of the field, would directly tend to alteration of the scale value, and introduce a variable parallax of serious amount.

The instrument now to be described is one of several forms contrived with the object of avoiding the difficulties encountered by those who have hitherto worked at this subject, and of extending the powers of the wire micrometer into the field occupied by the double image micrometer, by rendering the measurement of planetary discs and close double stars practicable without the production of interference phenomena, or the necessity of halving the light of the image, this last being a great objection to the use of the double image micrometer in the measurement of faint objects. At the same time the connexion between the several parts of the instrument is so rigid and permanent that variation in the scale value will be produced only by tempera-

ture, and the corrections thereby necessitated will be of the same order with those already familiar to observers.

Plate III., figure 5, represents the most simple form of the instrument hitherto devised by us, one-third of its actual size. Externally it consists of a pair of tubes, one in the axis of the telescope, and the other at right angles thereto. The first of these tubes is attachable to the draw tube by an ordinary 'Tulley' screw at S, and carries at its lower end the eyepiece E. The cross tube carries at one end a 'Reticule' or wire frame F, movable or stationary, according to requirements, and at the other a cell containing a concave silvered mirror M, the radius of curvature of which is slightly greater than the distance between F and M. At the junction of the tubes is mounted (at 45° to F. M) a plane silvered mirror PP, perforated by an elliptical hole slightly larger than is necessary to allow the pencil of rays from the object glass to pass. Immediately below PP is inserted a perforated achromatic lens LL to increase the convergence of the rays from M, thus diminishing the length of the eye tube, while forming an image of F at the focus of the object glass. F being illuminated by a faint external light the rays from it pass to M through the hole in PP, and being reflected by M in a cone of smaller angles are received on the inner edge of PP, and are thereby diverted into the eye-tube where they are still further condensed by LL and brought to a focus at F—the focus of the object glass.

In Plate IV., fig. 7, is shown the original form which Mr. Grubb placed for trial in Mr. Burton's hands. The principle is precisely the same, but greater compactness is obtained by bending back the rays as in Plate III., figure 5.

In some cases the lens L (Plate III., fig. 5) may be unnecessary, in others it may be found better to use a plane mirror at M, and throw the whole work of forming the 'ghost' images on the lens L. It is, of course, not necessary that the cross tube should be at *right angles* to the eye tube; and, in some cases, it may be advisable to use different arrangement of the parts. If it should prove to be difficult to adapt the instrument to any existing telescope on account of its length (4 inches), a Barlow lens can be inserted at S; but some forms of the apparatus have been devised, in which there is no cross tube, and the 'ghost' images

are formed by a perforated concave mirror, mounted in a tube capable of being pushed into the draw tube of the telescope. (See Plate III., fig. 6.) The best form of condensing lens L is under consideration, and it may possibly be found desirable to superachromatize it to compensate for the undercorrection of the usual eyepieces for lateral pencils.

In two of its simplest forms including that represented in the figure, the 'ghost' micrometer has been severely tested by one of us (Mr. Burton) as regards the effect of the images of the lines upon the images of various celestial objects formed by an equatorially mounted objective of six inches aperture and six focal length. The objects scrutinised for this purpose were the following:—Lunar details, near the terminator, and fully enlightened; Jupiter and Saturn, with their satellites; and numerous stars, both single and double. In all cases the result was the same, not the slightest change of form or false light beyond the limb (of the planets), being visible or even suspected when the objective images were brought in contact with or were occulted (covered) by the 'ghost' lines, powers up to 400 linear being employed whenever definition was suitable. The illumination of the reticules employed was extremely easy, and readily adjusted to suit the brightness of the object observed. It was possible, with the direct light of an ordinary candle, unassisted by any optical arrangement for rendering it parallel or convergent, to increase the brightnes of the lines sufficiently to make them clearly visible against the brightest parts of the moon's image. The reticules employed were systems of lines cut through an opaque film deposited upon glass.

Suggested forms of "Ghost" micrometers with their applications.

In its most simple form, this micrometer will do duty as a transit eyepiece displaying dark lines on a bright field, or r. r., and can be fitted with reticules of any kind for mapping groups of stars, or details of the moon or planets, including of course circles for ring micrometer work.

(1) By substituting for the reticule a wire micrometer with one or two screws, the instrument can be used (*a*) instead of an ordinary wire—or bifilar micrometer with bright field,

or (*b*) as a unifilar micrometer with bright lines cut through an opaque film; or (*c*) as a bifilar micrometer with bright lines, the object lines (at F), being in this case spider webs, illuminated by a Wenham paraboloid or other similar contrivance.

(2) By splitting the plane mirror P centrally in the plane M.P.E., and mounting one-half on an axis perpendicular to that plane, attached at its upper end to a lever arm terminating in a sector actuated by an endless screw with divided head, a double set of "Ghost" lines might be formed by inclining the two parts of the plane P to another by a movement of the arm screw. One of these sets of lines would be stationary, while the other set would have its movement registered by the turns and parts of a turn of the endless screw. Of course the lines might be either dark on a bright field or bright on a dark field, the latter being best; for in the former case, the lines would not be *black*, but would be of half the brightness of the field. We have experimentally proved that the definition of the lines is practically unaffected by stopping off half the aperture of M or P, in a direction perpendicular to them, and that their brightness does not sensibly diminish for a considerable distance past the centre of the field.

(3) By substituting diaphragms pierced with small circular apertures, as in the instrument of Professor Stampfer (*vide Note at end*), illuminated by polarized light variable in intensity and colour, this micrometer can be made available for photometric and colour comparisons of stars after the method of Zöllner, and not only can the field, in the case of bright field illumination, be illuminated with light of any desired tint, but, if bright lines are employed, they can be coloured as the observer may prefer, for there is always a superabundance of light, which is yet completely under control. The lines can be shown broken or continuous as may be desired. The first mentioned arrangement may be advantageous under some circumstances.

A useful modification of the reticule mentioned above, would be a bright ring (photographed), divided into numbered degrees, and nearly of the same diameter as the field, which would assist materially in estimation of position angles when the faintness of the object viewed rendered *measurements* impossible.

Lastly, when a slight loss of light is of no importance, a glass plate with plane and parallel sides, the preparation of which is a matter of no difficulty in the present state of practical optics, may be substituted for the plane mirror P, with the advantage of securing a large field, which may be surveyed by a low power eyepiece, or by one of high power so mounted as to be traversable over the whole field.

Many other forms and modifications have occurred to us, some of which may eventually be found practicable, but we deem it unnecessary to crowd this paper with suggested forms which have never been tried, and some of which will probably be useless.

The difficulties met with by Mr. Burnham, which originally drew the attention of one of the authors (Mr. Grubb) to this subject had reference mostly to adaptations of recording apparatus to micrometers, as he felt the great inconvenience of rising from his chair after making a bisection, probably in some most awkward position, to read his micrometer head and circles with the aid of a hand lamp. We have had some experience of recording apparatus attached to circle microscopes, and while we believe in their feasibility, we question the desirability of such attachments to delicate instruments.* We believe, however, that the same end can be obtained by some simple adaptations to this new form of micrometer.

It does not take much imagination to conceive an optical

* In some cases the recording apparatus consisted merely of an arrangement for producing ink dots on an ivory head attached to micrometer head, and thus five or six observations could be made, and all read off together. In the case of a special micrometer, however, made for the Earl of Rosse, one of the authors (Mr. Grubb) adapted a peculiar system which has not been elsewhere described. The micrometer head terminated in a flat plate, represented in fig. 4 plate II., by the central circle *a a*. Surrounding this, and in same plane, was a ring, *b b b*, which formed part of a wheel centered on the micrometer head, and by a simple contrivance caused to revolve once for every ten revolutions of head itself. Surrounding this again was another ring, *c c c*, stationary. The plates *a a a*, therefore, revolved with the screw directly, *b b b* at ten times this speed, and *c c c* was always stationary. In the centre was a small point, *d*, and on outside ring two smaller points, *e* and *f*. A similar needle point was fixed in some part of each of the rings *b b b* and *c c c*, as at *g* and *h*. A folding piece of brass, covered with cardboard or indiarubber, was hinged in such a position that a piece of paper could be conveniently applied to and stamped against the end of the micrometer head. The stamping produced five holes, *d e f g* and *h*. A line drawn through *d e f* gave the zero, the angular position of *g* gave the whole turns of micrometer screw, and that of *h*, the angular position of the micrometer screw itself; or, in other words the reading of the micrometer head.

In reading off these records the next day the paper was placed under a glass scale, divided in one annulus, to read the whole turns and on the other the parts of a turn, the point *d* giving the centre, and *e* and *f* the zero of the scale.

arrangement of mirrors such, that after a bisection is satisfactorily made, images of the divisions of the micrometer heads and position circles could be thrown into the field of the same eye-piece just as the image of the reticule is here thrown in, and then the readings of all the graduations could be taken without shifting the eye from the eye-piece of the telescope.

Lastly, as to the source of illumination. The illumination of this micrometer is a much simpler matter than in any other form of micrometer for bright line illumination, on account of the small quantity of light required. Still, if some simpler plan could be contrived that would enable a source of faint light to be placed close to the micrometer, instead of having to throw it from a distance, or conduct it down the tube by mirrors, &c., a great advantage would be gained. We are, therefore, engaged in experiments to investigate whether such illumination could not be obtained from platinum wire or carbon rendered incandescent by an electric current of low tension. These experiments are mentioned to show that every branch of the subject is receiving due attention.

NOTE.—Since this paper was read we have had an opportunity of examining the original papers of Dr. Lamont, Dr. Littrow, as well as notes on a kindred instrument devised by Professor Stampfer of Vienna, by himself and by Herr Reslhüber, Director of the Observatory of Kremsmünster in Bavaria. Dr. Lamont used a glass plate, set transparently at a small angle with the optic axis of the telescope to introduce the image of the lines into the field of the eye-piece. Professors Littrow and Stampfer's instruments are essentially similar, the images of the points or lines employed being formed by a small segmental lens immediately outside the cone of rays from the O. G., the lines or points used being external to the telescope tube and at one side of it, and the light from them directed to the image-forming lens by a small prism of total reflection. The beam of light was thus unilateral, and the principle of the instrument identical with that figured on Plate III., fig. 5. Professor Stampfer preferred bright points to bright lines, which last were used by Dr. Littrow.

II.—ON A TRAVERTINE FROM BALLISODARE, NEAR SLIGO, CONTAINING A CONSIDERABLE AMOUNT OF STRONTIUM, BY EDWARD T. HARDMAN, F.C.S.

[Read, May 21st, 1880.]

Along the shores of the minor bays which indent the coast near Sligo, there is often a considerable deposit of travertine, owing to the water which trickles over the limestone cliffs, dissolving a portion of the carbonate of lime, and again depositing it in a porous form on the slope. Travertine is thus found in abundance at Drumcliff Bay, to the north, and at Ballisodare Bay, to the south; and that at the latter place is interesting from the fact that it contains a very appreciable amount of the rare metal, strontium—probably the only instance in which it is known to occur in a recent calcareous deposit.

The manner in which I noticed this is sufficiently curious to be mentioned. A silver-lead, and zinc mine is at present being worked close by. A mining captain, who was brought from England to examine this, saw the travertine deposit, declared it to be zinc ore, equal to anything he had seen in Spain, and took some specimens for analysis to England. The owner asked my opinion about it, and was incredulous when I pronounced it to be common travertine. However, eventually it was proved to the satisfaction of himself and his practical friend that it was nothing else.

As I had been making some researches on the presence of zinc in limestone rocks, I obtained some specimens for analysis, deeming it likely that from its proximity to the zinciferous limestone the deposit might contain a small amount of the metal. It proved, however, to contain not the slightest trace; but in the course of the examination the presence of strontium was clearly marked.

It is easy to render this visible. Chloride of strontium is soluble in alcohol, and on ignition gives out the well known crimson colour.

Taking some of the travertine, therefore, and placing it in a vessel with hydrochloric acid and alcohol, and then setting fire to the mixture, the presence of the strontium is at once apparent.

The composition of the travertine is as follows :--

Carbonate of Lime,	91·05	
Carbonate of Magnesium,	4·50	
Carbonate of Strontium,	2·15	—3·5
Ferric Oxide and Alumina,	1·80	
Insoluble residue,	0·50	
	100·00	

III.—PRELIMINARY NOTE ON THE MANUFACTURE OF PAPER FROM MOLINIA CŒRULEA, BY W. SMITH.

[Read, November 15th, 1880.]

THE botanical name of Melic Grass, which, with paper made from it, is exhibited, is *Molinia cœrulea,* but for the purpose of indicating the use for which it is so well suited, I have called it "Irish Esparto."

The natural habitat of this grass or sedge appears to be bog, though it is sometimes found on clay land.

It is easily distinguished by the seed stems, and by the absence of knots on these stems, except one close to the root. It grows in tufts, or rather mats, sometimes of considerable size, on the margin of bogs or sides of bog drains, ditches, and where the surface of bogs has been dug up, or in some way deprived of its natural growth of heath, &c., &c.

It is generally known that Esparto is extensively used in the manufacture of paper, its use for this purpose may be said to date only from about 1860.

It is as a paper making material, and a rival of Esparto, to which it bears some resemblance, that the Melic Grass promises to be of commercial importance.

The paper exhibited has been made solely from the grass gathered this year on the bogs at Tyaquin, in the County Galway, on the estate of Mr. N. S. Richardson, who has made some experiments in cultivating the grass from seed. Last year Mr. Richardson sent me some of the grass, which I tested as to its paper making qualities; and, though the quantity sent was small, and the trial was the first ever made, the result was so favourable that several Galway gentlemen joined Mr. Richardson in experimenting on the best method of growing the grass. The information obtained from these trials and from observation of its natural habit, is that the grass grows well on partially drained bog, that when by accident or design the surface of the bog had been burned, there the grass was most luxuriant—in some cases springing up after a fire in places where it had not previously

been observed. It seems to confine itself to flat bogs, as I have not found it, nor have I met anyone who has seen it growing on mountain bogs. I have found it growing luxuriantly in the counties Galway, Roscommon, King's, Kildare, and Fermanagh, and have received samples from Kerry and Donegal; so that it is probable the grass will be found more or less in all the flat bog districts of the country. It is said to have been formerly used in the Island of Skye for the manufacture of fishing nets. It is now used in Kerry for making creel handles, and is locally known as fedget grass.

From the trials already made, both in quality and yield of paper, the grass appears at least equal to Spanish and Algerian Esparto. Two independent trials—one in Scotland—are now in progress, which I have no doubt will confirm the favourable results already arrived at.

From 1860 to the present time the use of Esparto has been gradually increasing, and now the import amounts to nearly 200,000 tons per annum, at prices varying from £5 to £10 per ton, according to quality and supply. As each year the yield per acre of Esparto diminishes, to keep up the supply, it has to be gathered from a constantly extending area; and as the American paper makers have now begun to use Esparto, the supply to England is likely to be diminished or the cost increased.

There are in Ireland upwards of 1,000,000 acres of flat bog, at present useless for any agricultural purpose. The entire of this area might be made to grow "Irish Esparto." Mr. Richardson estimates the yield to be about half a ton to the statute acre if grown as a crop; and, therefore, to supply the English market, some 400,000 acres of what is at present a wet spongy mass would require to be drained, and, as considerable quantities might be exported to America, the area of bog to be drained need not be limited by the home demand. One obstacle to the drainage of bogs has hitherto been that there was no known crop of any value which could be grown on partially drained bog. The Melic Grass, which is a perennial, supplies this want, and there is now no reason why a large portion of these worse than useless bogs should not be drained, and the climate not only of their own immediate neighbourhood, but also of the country in general, be improved.

As the value of the grass at a railway station, canal, or seaport would be at least £3 per ton, its cultivation is worth the attention of bog owners, and of exceptional assistance from Government, by loans for drainage through the Board of Works, at the lowest possible rate of interest. The cost of draining 400,000 acres, so that they might grow Melic Grass, would not amount to one million sterling, as the partial drainage of deep bog, sufficient to prevent the accumulation of stagnant water on the surface, is comparatively an easy matter.

In addition to the employment which would be given in cultivating the grass, another industry might be created by making the grass into "paper stock." Wherever a sufficient quantity might be grown, peat being used as fuel, the quantity of material to be exported would be considerably reduced, whilst the value would be more than doubled. It is even quite possible that it might be cheaper to manufacture the Caustic Soda which would be required on the bog, than to import it from England, as on a bog, turf is certainly a cheap fuel.

IV.—NOTES ON SOME NEW OR RARE IRISH HEPATICÆ, BY DAVID M'ARDLE. PLATES 5 AND 6.

[Read, November 15th, 1880.]

It is now more than four years since the late Dr. Moore read before the Royal Irish Academy his "Report on Irish Hepaticæ," the result of many years research and investigation of this interesting tribe of cryptogams. In this paper he enumerated 137 species, and appended to it a list of all previous papers and works relating to the Hepaticæ of Ireland.

Since the publication of that Report* a few additional species have been determined, and new localities for some of the rarer ones have been discovered, which were hitherto confined to one locality. The record of these additions forms the subject of the present paper.

I had the honour of accompanying the late Dr. Moore in many of his excursions through the country in search of Hepaticæ and mosses, and remember that on one of these occasions when collecting on the damp sandy flats at Malahide where the rare *Codonia Ralfsii* and *Palavicinia Hibernica* are found, he pointed out to his son, Mr. F. W. Moore, the present Curator of the Royal Botanic Garden, Glasnevin, and to me, a single plant of the rare *Scalia Hookeri* (Lyell) B. Gray. This unique specimen we unfortunately lost before reaching home, and consequently had only the opportunity of examining it in the field with a pocket lens. There can be no doubt as to its being the right plant, and probably it occurs in some quantity in the locality where before long we hope to make a careful search, and endeavour to verify the station. The only authority for recording *Scalia Hookeri* as an Irish plant was from a small portion collected at Connor-hill near Dingle, county Kerry, in 1873, by Dr. Lindberg of Helsingfors. To the genus Cesia I have added two species hitherto unknown to occur in Ireland, it being held by many good botanists that we have but one—viz., *C. crenulata*, Gott. When looking over the specimens in the Herbarium at Glasnevin, there were two packets containing specimens which I

* Proceedings of the Royal Irish Academy, Vol. 2, Ser. 11—Science, p. 591.

thought different from the type; I therefore sent them to Professor Lindberg, who identified them as *C. coralloides* and *C. obtusa.* Though closely allied to each other, they are nevertheless quite distinct from *C. crenulata,* and when our eyes get accustomed to their distinguishing characters they will be easily recognised, and no doubt will be found to be as widely distributed as the old species. I have made rough drawings of both species to enable the student to distinguish them. The material at my disposal for drawing was not all that could be wished, having been a long time collected and sterile. A good description and figure of *C. coralloides* is given in Carrington's British Hepaticæ, Part I., page 9, Pl. I., Fig. 3. It is very rare in Scotland, and has a geographical range northwards to Lapland. I have lately received a packet of specimens of *C. obtusa* from Mr. J. Sim, who collected them on Mount Strade, Aberdeenshire, October, 1880, and they agree in every respect with the Irish specimens named by Lindberg.

Cesia, Bennett Gray.

Jungermannia. Lightfoot, Fl. Scot. 2, p. 786 (1770); Hook. Brit. Junger (1816). Cesia, B. Gray, in Gray's Nat. Arr. Brit. Pl. I., p. 705, 1851. Gymnomitrium, Corda, in Opiz. Beitr. 1, p. 651, 1829.

Involucral leaves several, Colesule wanting. Bases of the pistillidia immersed in the hollow apex of the stem. Antheridia axillary. Amphigastria none.

Cesia coralloides, Lindberg.

Resembling the common *C. crenulata,* Gott, but smaller and not so much branched, branches erect, clavate, of a dull white colour, growing in compact patches. Leaves closely imbricated, emarginate, margin plane with none of the cells projecting as in *C. crenulata.*

Hab. Brandon Mountain, county Kerry—Dr. Moore, 1840.

Cesia obtusa, Lindberg.

Closely allied to the preceding, stems erect, regular in outline, longer and more slender, very much branched, of a dark olive

colour. Leaves oblong, emarginate, sinus obtuse, margin plane, closely imbricated, more so than in the last, and with difficulty detached perfect.

Hab. Mwellrea Mountain, county Mayo--Dr. Moore, 1874.

Lejeunea patens, Var. cochleata, Spruce.

Hab. Glenfarm demesne, county Leitrim, 1875; Kylemore, county Galway, 1874, and on Benbulbin, county Sligo, 1871—Dr. Moore.

This very distinct variety is generally found growing on the larger Hepaticæ, such as *Radula, Frullania,* &c., and creeping amongst the branches of *Thamium alopecurum.* It at first sight appears to be distinct, but when a patch is closely examined where it is growing, some stages of its growth are to be found so close to the normal form as to show that they cannot be separated from it.

Lejeunea flava, Swartz. L. cavifolia β planiuscula, Lindberg.

Hab. Cromaglawn, Killarney, 1873—Dr. Moore.

Closely allied to *L. Moorei,* Lindberg, but is more branched, leaves more closely placed. Amphigastria smaller and more cordate at the base.

Formerly collected at Killarney by Dr. J. F. Mackay, but not again observed until rediscovered by Dr. Moore in 1873.

Cephalozia bicuspidata γ uliginosa, Nees. Syn. Hepat., pp. 139.

O'Sullivan's Cascade, Killarney, July, 1869, and in same year on wet bogs near Kylemore, county Galway, Dr. Moore. Killakee Glen, Dublin Mountains, May, 1874. Loughbray, county Wicklow, September, 1877.

This form is new to the Irish Flora.

Cephalozia cladorhizans, Spruce.

C. obtusiloba, Lindberg. Jungermannia inflata δ fluitans, Synops. Hepat., p. 105, n. 68.

Hab. Wet bogs near Kylemore, county Galway, May, 1869—

Dr. Moore. Bracklin bog, near Killucan, county Westmeath, growing on *Sphagnum rubellum* and *S. cuspidatum.*

Apparently closely allied to *J. inflata,* the stem is unbranched or rarely branched, attenuated, flagelliferous, of a bright green colour, leaves distantly placed, divided to about one-third of the leaf into two obtuse lobes. This is also new to the Irish Flora, but it is well known on the Continent.

The specimens collected in both the localities mentioned above are covered with the *Zygogonium ericetorum* one of the conjugate algæ, which appears to injure the leaves, and adheres so closely to the stem that small portions might be mistaken for amphigastria. A figure of this plant is given in Plate VI.

Scapania curta, Dumort.

Jungermannia nemorosa δ denundata Hook. Brit. Jung., t. 21.

Hab. Upper Lough Bray, county Wicklow, 1879. Growing on the decaying stems of Ulex. This is a new locality for the species.

Jungermannia (*Aplozia*) *cuneifolia* (Hook.), Dumort.

Hab. Connor Hill, near Brandon Mountain, county Kerry, 1877. Growing parasitically on *Frullania Tamarisci.* This curious minute species, which is very rare in Ireland, was previously confined to Killarney. It may be known from all the other species by its curiously wedge-shaped leaves.

Jungermannia (*Lophozia*) *ventricosa,* Dicks.

Hab. Connor Hill, near Brandon Mountain, county Kerry, though widely distributed is rare in the county Kerry.

Amongst the various communications recently sent to Glasnevin, the most interesting was one containing a quantity of good specimens of *Anthelia Turneri,* Dumort. It was found by G. Davies, Esq., in North Sussex. This plant was hitherto confined to Ireland, where it was first collected by Miss Hutchins, near Bantry, county Cork, in 1811, and was not reported to have

been collected by any one until Dr. Lindberg found it at Killarney, in June, 1873.

The rare *Lejeunea patens* and *L. Moorei* both occur in Scotland, having been found by Mr. J. Sim in Aberdeenshire. From Mr. Sim I have also received many specimens of Scottish Hepaticæ, amongst them I may mention *Cephalozia elachista ; Jungermannia cordifolia, J. capitata,* and *J. Dicksoni,* all rare Irish plants, which show an interesting geographical distribution.

Reference to Plates.

Plate V. Fig. I. Cesia coralloides, Lindberg. Plant natural size ; 2, highly magnified ; 3, outline of leaf highly magnified ; 4, cells magnified × 250 diameters.

Fig. II. 1, Cesia obtusa, Lindberg. Plant natural size ; 2, highly magnified ; 3, leaf and cells, × 250 diameters.

Plate VI. Fig. III. Cephalozia cladorhizans, Spruce, = C. obtusiloba, Lindberg. 1, Plant natural size ; 2 and 3 highly magnified ; 4, leaf and portion of stem highly magnified.

V.—NORTH-AMERICAN BIRDS CROSSING THE ATLANTIC, BY PERCY EVANS FREKE.

[Read, November 15th, 1880.]

THE following tables are based upon a paper which I read before this Society last year, entitled " A comparative Catalogue of Birds found in Europe and North America," (*vide* Proceedings, Vol 2, n.s., p. 373). In the present article I have selected only those occurrences which seem to be generally accepted as authentic by the best authorities. This has entailed a very large reduction in the number of instances quoted, which now amount to 394, and it also curtails considerably the list of species by the omission of such birds as the *Nyctale acadica* and *Scops asio.* Others, also, such as *Chen hyperboreus* and *Puffinus obscurus,* may have come to us across the Atlantic, yet as they inhabit Africa or Asia as well as America, they have been omitted here, as have such birds as *Thalassidroma oceanica* which make the ocean their home, with a widely extended range. I have, however, included *Xema sabinii,* for although it probably may be considered as belonging to northern Asia, yet our European specimens being taken in the west, may I think fairly claim to have come to us from America, especially when we consider the prevalence of strong winds from the west, and the greater liability of stragglers to be found east of their natural habitat. In the case of *Bernicla canadensis,* I have only included the two examples which have occurred at the Faroe Isles, as its presence with us in numbers as an ornamental waterfowl throws great doubt upon its occurrence here in a really wild state.

In preparing this paper I have received the greatest assistance from the excellent article of Mr. Dalgleish, * which has lately appeared in the Bulletin of the Nuttall Ornithological Club, and which may now be considered as the standard authority on the subject.

As a means of arrangement I have placed the different species under the three heads of land birds, waders, and swimming birds, as I think this plan best agrees with the manner in which they have been influenced by the circumstances attending their immigration.

* " List of Occurrences of North American Birds in Europe," by J. J. Dalgleish. Bulletin of the Nuttall Ornithological Club, Vol. V., Nos. 2, 3, and 4 (1880).

Of land birds there are 120 occurrences belonging to thirty-one species. Of these one occurred in Iceland; and thirty-three including fifteen species, only in the British Isles. Fifteen belonging to seven species have been found in Ireland, of which *Ceryle alcyon* has occurred nowhere else in Europe, *Coccyzus erythrophthalmus* only in Ireland and Italy, and *Astur palumbarius Var. atricapillus* only in Ireland and Scotland.

Twenty-seven occurrences, of ten species are recorded from Scotland, of which *Buteo lineatus* has not occurred elsewhere in Europe.

England is credited with fifty-three cases belonging to eighteen species, of which twelve including seven species, have occurred nowhere else in Europe, and *Turdus migratorius* has been found only in England in the British Isles, although it has also occurred on the continent of Europe. *Progne subis* is recorded only from England and Ireland, and *Regulus calendula, Zonotrichia albicollis, Surnia ulula Var. hudsonica* and *Nauclerus furcatus* only in England and Scotland.

Nine instances belonging to eight species have occurred in the small island of Heligoland, and of these *Harporhynchus rufus, Galeoscoptes carolinensis, Anthus ludovicianus, Dendroica virens* and *Charadrius virginicus* have occurred nowhere else in Europe.

We have records also from Spitzbergen, Sweden, Germany, Pomerania, Austria, Belgium, Switzerland, and Italy.

Of those occurrences where I have been able to ascertain the monthly date, eight have taken place in February; six in March; eight in April; four in May; four in June; one in July; two in August; five in September; eleven in October; five in November; and nine in December. Thus in the six months from October to March inclusive, thirty-nine out of sixty-three, or nearly sixty-two per cent. of all the occurrences have taken place; besides which there are five marked spring; two summer; ten autumn, and one winter. For the spring (March, April, and May) twenty-three cases, as compared with thirty-one for the autumn months (September, October, and November).

Of wading birds 125 instances are recorded, comprising sixteen species. One *Numenius hudsonicus* has occurred in Iceland. In Ireland we find twelve occurrences, including six species, of

which *Porphyrio martinicus* has been found there only. In Scotland there are sixteen cases of seven species, of which *Rhyacophilus solitarius* has occurred nowhere else in Europe. In England there are eighty-two occurrences, including twelve species, of which one of *Gallinago wilsoni*, two of *Tringa minutilla*, and three of *Gambètta flavipes* have occurred in England alone, *Tringa maculata* only in England and Scotland, and *Tringa fuscicollis* only in England and Ireland.

On the continent of Europe, one occurrence each is reported from Heligoland, Holland, Malta, Italy, and Spain ; two from Germany, and five of three species from France.

In those cases in which I have obtained the monthly date, I find that two have occurred in January, two in March, one in April, six in May, one in June, two in July, five in August, twenty in September, twenty-eight in October, thirteen in November, and five in December. Therefore in autumn, including September, October, and November, we have received sixty-one out of the whole eighty-five occurrences, or more than 71 per cent., besides four cases marked autumn and one winter, to contrast with only nine in spring.

Of swimming birds there are 149 instances of twenty-two species.

From the Faroe Isles we have seven records of three species.

From the British Isles 103 records of nineteen species, of which thirty-seven of nine species have occurred there only.

In Ireland there are twenty-four instances of seven species, of which *Chen albatus* and *Anous stolidus* have occurred nowhere else in Europe. Scotland is credited with twenty-three cases belonging to nine species, of which *Cygnus americanus* has occurred there only, and *Clangula albeola* only in England and Scotland.

From England are recorded fifty-six cases, including sixteen species. Of these eight cases of four species have occurred nowhere else in Europe, and one, *Fuligula affinis* only in England and Holland, and another, *Æstrelata hæsitata,* only in England and France.

From the rest of Europe thirty-eight occurrences, belonging to twelve species, are recorded from Spitzbergen, Munsterland, Sweden, Russia, Heligoland, Holland, France (including Picardy)

Germany, Holstein, Austria, and Italy; *Phaleris psittaculus* having been found only in Sweden, and *Uria columba* only in the Spitzbergen seas.

Where I have ascertained the date, I find that, out of ninety-two occurrences, six have taken place in January, six in February, four in March, three in April, four in May, six in June, one in July, eight in August, twelve in September, fifteen in October, five in November, and four in December, while one is marked spring, one summer, four autumn, and twelve winter. Altogether twelve instances in spring as against thirty-six in autumn.

Concerning the routes and means by which these visitors have reached us from America I can say but little.* A few may have escaped from aviaries or from ornamental waters, and in our climate, having met with surroundings not very different from those of their native land, and having been for some time at liberty, and successfully accomplished their moult, they may have become indistinguishable from a purely wild bird. But I am of opinion that their number is but few. Among the land birds it is highly improbable that the small warblers, the cuckoos, the kingfishers, and others, which are seldom or never kept in confinement, should have been brought over here as caged birds, and the large percentage of all which occur in the latter part of autumn or in winter (especially among the waders) would lead us to suppose that they were members of the great flocks of American birds which breed every summer in the north, where the Atlantic is contracted to its narrowest limits, and the eastern land most nearly approaches to the west. On their return southward their numbers are composed largely of young birds who are seeking a land where they have never been before, and who, from their youth, are less able than their parents to contend with rough weather and contrary winds. Adverse gales carry them far to the eastward, and, blown out of their course, their return is impossible against the strong westerly winds which prevail so much at this time of the year, and by which they are borne irresistibly eastwards, a few of those who survive finally reaching our shores in company with our own migrants returning from the north.

The comparative absence of American visitors from the flocks migrating northward in spring along our coasts, is easily accounted

* On this subject *vide* Professor Baird's article in the "American Journal of Science and Art," Vol. XVI. May, 1866.

for by the reverse of the conditions referred to above. The birds are older and stronger; the Atlantic further south is a great expanse of ocean, across which few birds, whose home is not upon the open sea, could ever pass unaided, and the easterly winds which so often prevail in spring would also probably prevent, even the most aquatic of the American birds, from visiting us at this season.

The very large proportion of these visitors which have been recorded from the British Isles, especially from England, as compared with the rest of Europe, is most striking; but this arises probably from the number of reliable observers being much greater in England than upon the Continent.

In conclusion, the most decided result which I have obtained is the remarkable preponderance in the number of birds which have visited us during the autumn and winter months, which I propose to join together as representing the autumn migration, both because many of the birds must have arrived upon our coasts in autumn, although not captured or recognised until long afterwards, and others have been driven to us from time to time during the winter, under the pressure of cold winds, snow, or a continuance of unusually severe weather.

Altogether we have forty-two arrivals for the spring migration, during March, April, and May, to which I think we may fairly add the nineteen more instances in June and July, making sixty-one. While for the autumn migration there are 132 in September, October, and November, to which, if we add the fifty-four winter occurrences from December to February, we shall have 168 to represent the autumn migration, which appears to be the period during which we receive by far the greater number of our Trans-atlantic visitors.

TABLES

SHOWING

NORTH-AMERICAN BIRDS WHICH HAVE CROSSED THE ATLANTIC.

Land Birds.

No.	—	Total No. of Occurrences.	Iceland and Faroe Isles.	Ireland.	Scotland.	England.	Continent of Europe.
1	Turdus fuscescens,	1	.	.	.	.	1 Pomerania.
2	Turdus swainsoni,	3	.	.	.	.	1 Heligoland. 1 Belgium. 1 Italy.
3	Turdus pallasi,	3	.	.	.	.	1 Heligoland. 1 Germany. 1 Switzerland.
4	Turdus migratorius,	6	.	.	.	1	1 Heligoland. 1 Germany. 3 Austria.
5	Harporhynchus rufus,	1	.	.	.	.	1 Heligoland.
6	Galeoscoptes carolinensis,	1	.	.	.	.	1 Heligoland.
7	Regulus calendula,	2	.	.	1	1	
8	Anthus ludovicianus	2	.	.	.	.	2 Heligoland.
9	Dendroica virens,	1	.	.	.	.	1 Heligoland.
10	Progne subis,	2	.	1	.	1	
11	Hirundo bicolor,	1	.	.	.	1	
12	Vireosylvia olivaceus,	2	.	.	.	2	
13	Loxia leucoptera,	11	.	.	4	7	
14	Zonotrichia albicollis,	2	.	.	1	1	
15	Agelaius phœniceus,	11	.	.	2	8	1 Italy.
16	Sturnella magna,	3	.	.	.	3	
17	Ceryle alcyon,	2	.	2	.	.	
18	Coccyzus americanus,	6	.	2	.	3	1 Belgium.
19	Coccyzus erythrophthalmus	2	.	1	.	.	1 Italy.
20	Picus villosus,	3	.	.	.	3	
21	Picus pubescens,	1	.	.	.	1	
22	Colaptes auratus,	1	.	.	.	1	
23	Surnia ulula var. hudsonica,	4	.	.	2	2	
24	Falco candicans,	30	1 Iceland.	6	13	9	1 Spitzbergen.
25	Nauclerus furcatus,	5	.	.	1	4	
26	Astur palumbarius var atricapillus.	3	.	2	1	.	
27	Buteo lineatus,	1	.	.	1	.	
28	Haliaëtus leucocephalus,*	1	.	.	.	.	1 Sweden.
29	Ectopistes migratorius,	7	.	1	1	4	1 Austria.
30	Charadrius virginicus,	1	.	.		.	1 Heligoland.
31	Ægialitis vociferus,	1	.	.	.	1	
		120	1	15	27	53	24

* Dalgleish. Bull. Nutt. Orn. Club, Vol. V., No. 3, p. 143.

Land Birds.

No.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.	.	.	.	.	.	.	.	.	.	.	.
2	.	.	.	.	.	.	.	.	.	69	.	.
										47		
									Autumn	43		
3	.	.	.	.	.	.	.	.	Autumn	36	.	.
												25
4	.	.	Spring.	76	.	.	.	.	.	.	.	.
										74		
												51
									Autumn	46		20
5	..	.	.	.	.	.	.	.	Autumn	38	.	.
6	.	.	.	.	.	.	.	.	.	40	.	.
7	.	.	..	.	.	Summer	52	.	.	.	.	.
8	.	.	.	.	58	.	.	.	.	.	51	.
9	.	.	.	.	.	.	.	.	.	58	.	.
10	.	.	.	.	.	.	.	.	.	.	.	.
11	.	.	.	.	.	.	.	.	.	.	.	.
12	.	.	.	.	59 }	.	.	.	.	.	.	.
					59 }							
13	.	41	.	49 }	.	.	.	.	45	.	.	.
				49 }					59 }	44	.	49
				49 }					59 }			
				49 }								
14	.	.	72	.	.	.	.	67	.	.	.	.
15	.	.	66	.	65	43	.	.	Autumn	44	.	63
			67			66				74		
16	.	.	.	.	.	.	.	.	.	.	.	.
17	.	.	.	.	.	.	.	.	.	45	45	.
18	.	.	.	.	.	.	.	.	Autumn	25	.	.
									Autumn	32		
										70		
										74		
19	.	.	.	.	.	.	.	.	71	.	.	.
20	.	.	.	.	.	.	.	.	.	.	.	.
21	.	.	.	.	.	.	.	.	.	.	.	36
22	.	.	.	.	.	.	.	.	Autumn	36	.	.
23	.	.	30	.	.	.	.	47	.	.	68	.
24	.	37	66	75	.	.	61	.	Autumn	62	51	47
		37	76	76					Autumn	62	54	
		38										
		48	Spring.	62							Winter.	68
		63	Spring.	63								
25	.	.	.	53	.	Summer	33	.	05	.	.	.
						43						
26	.	70	Spring.	69	.	.	.	.	.	.	.	.
			Spring.	70								
27	.	63	.	.	.	.	.	.	.	.	.	.
28	.	.	.	.	.	.	.	.	.	.	.	.
29	.	.	.	.	.	44	.	.	.	76	.	25
30	.	.	.	.	.	.	.	.	.	.	.	47
31	.	.	.	57	.	.	.	.	.	.	.	.
		8	6	8	4	4	1	2	5	11	5	9

In cases where more than one bird has been taken on the same occasion, or from the same flock, I have included the dates within a bracket.

Wading Birds.

No.	—	Total No. of Occurrences.	Iceland and Faroe Isles.	Ireland.	Scotland.	England.	Continent of Europe.
1	Botaurus lentiginosus, . .	17	.	3	6	8	
2	Gallinago Wilsoni, . . .	1	.	.	.	1	
3	Macrorhampus griseus, . .	15	.	.	3	9	3 France.
4	Tryngites rufescens, .	20	.	4	1	13	1 Heligoland. 1 France.
5	Symphemia semipalmata, .	3	.	.	.	.	3 France.
6	Tringa maculata, . . .	19	.	.	1	18	
7	Tringa minutilla, . . .	2	.	.	.	2	
8	Tringa fuscicollis, . . .	14	.	1	.	13	
9	Gambetta flavipes, . . .	3	.	.	.	3	
10	Rhyacophilus solitarius, . .	1	.	.	1	.	
11	Tringoides macularius, . .	11	.	2	2	6	1 Germany.
12	Actiturus longicaudatus, .	10	.	.	.	6	1 Germany. 1 Holland. 1 Italy. 1 Malta.
13	Numenius hudsonicus, . .	2	1*	.	.	.	1 Spain.
14	Numenius borealis, . . .	5		1	2	2	*Iceland.
15	Porzana carolina, . . .	1	.	.	.	1	
16	Porphyrio martinicus, . .	1	.	1	.	.	
		125	1	12	16	82	14

Wading Birds.

No.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.	.	73	.	.	.	.	.	. Autumn Autumn	44 70 70 75 04 62	45 54 68 77	29 45 51 71
2	.	.	.	.	.	.	.	63	.	.	.	.
3	.	.	.	.	.	.	.	.	35 58 Autumn	01 45 57 62 36	.	.
4	.	.	.	.	29 47	.	82	51	26 41 43 46 60 70 Autumn	64 39	.	.
5	.	.	.	.	.	.	.	.	.	.	.	.
6	68	.	.	.	40	55	.	53	53 65 70 70 70 70 70 71	30 41 53 67 70	.	.
7	.	.	.	.	.	.	.	.	69	53	.	.
8	.	.	.	.	.	.	.	.	.	46 54 57 70 70	70 70 70 70 70	.
9	.	.	.	.	.	.	.	.	.	58 71	Winter	54
10	.	.	.	.	.	.	.	.	.	.	.	.
11	.	.	49	75	63 63	.	28	67 67	28	66 66	.	.
12	55	.	.	.	.	.	.	.	.	51 59	65 65 79	54
13	.	.	.	.	72	.	.	.	.	.	.	.
14	.	.	.	.	.	.	.	.	55 78	70	.	,
15	.	.	.	.	.	.	.	.	.	64	.	.
16	.	.	.	.	.	.	.	.	.	.	45	.
	2	.	2	1	6	1	2	5	20	28	13	5

Swimming Birds.

No.	—	Total No. of Occurrences.	Iceland and Faroe Isles.	Ireland.	Scotland.	England.	Continent of Europe.
1	Cygnus americanus, (?) . .	1	.	.	1	.	
2	Cygnus buccinator, . .	4	.	.	.	4	
3	Chen albatus, ...	5	.	5	.	.	
4	Bernicla canadensis, . .	2	2 Faroes.	.	.	.	
5	Mereca americana, . . .	7	.	2	1	3	1 France.
6	Querquedula discors, . .	4	.	.	1	2	1 France.
7	Querquedula carolinensis, .	2	.	.	.	2	
8	Fuligula collaris, . . .	1	.	.	.	1	
9	Fuligula affinis, . . .	2	.	.	.	1	1 Holland.
10	Clangula albeola, . . .	5	.	.	2	3	
11	Œdemia perspicillata, . .	34*	3 Faroes.	1	10	4	3 Russia. 3 Sweden. 1 Heligoland. 8 France.
12	Mergus cucullatus, . . .	15	.	2	4	9	
13	Phaleris psittaculus, . .	1	.	.	.	.	1 Sweden
14	Uria columba, . . .	1	.	.	.	.	1 Spitzbergen.
15	Puffinus griseus, . . .	9	2 Faroes.	.	1	4	2 France.
16	Æstrelata hæsitata, . .	2	.	.	.	1	1 France.
17	Larus atricilla, . . .	6	.	.	.	4	1 France. 1 Austria.
18	Larus philadelphiæ, . .	7	.	3	1	2	1 Heligoland.
19	Xema sabinii, ...	32	.	8	2	13	2 Munsterland. 1 Holstein. 1 Heligoland. 1 Holland. 1 Picardy. 3 France.
20	Sterna fuliginosa, . . .	5	.	.	.	2	1 Germany 1 France. 1 Italy.
21	Sterna anæstheta, . . .	1	.	.	.	1	
22	Anous stolidus, . . .	3	.	3	.	.	
		149	7	24	23	56	38

* Including one, locality unknown.

Swimming Birds.

No.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.	41	.	.	.	.	.	.	.	.	.	.
2	.	.	.	.	.	.	.	.	.	66	.	.
										66		
										66		
										66		
3	.	.	.	.	.	.	.	.	.	77	71	.
										77	71	
4	.	.	79	.	.	.	.	.	.	66	.	.
5	41	44	.	70	.	.	.	.	.	.	Winter.	37
	64			75								
6	63	.	.	.	.	.	.	.	.	.	.	.
7	.	.	.	.	.	.	.	.	.	.	79	.
8	.	.	.	.	.	.	.	.	.	.	.	.
9	.	.	.	.	.	.	.	.	.	.	.	.
10	65	.	.	.	.	.	.	.	.	.	Winter.	30
											Winter.	41
											Winter.	64
11	78	75	66	.	76	46	.	56	56	51	69	75
		76				47				67	75	77
						Summer	58	.	Autumn	53		79
											Winter.	35
											Winter.	41
											Winter.	51
											Winter.	65
12	.	.	70	.	53	.	.	.	.	.	Winter.	29
			70		53						Winter.	30
					53						Winter.	40
13	.	.	.	.	.	.	.	.	.	.	.	60
14	.	.	.	.	.	.	.	.	.	.	.	.
15	.	.	.	.	.	75	.	28	72	79	.	.
								73	76			
16	.	.	Spring.	50	.	.	.	.	.	.	.	.
17	.	.	.	.	.	77	.	74	.	.	Winter.	50
18	45	48	.	50	.	.	64	.	Autumn	64	.	.
		55										
19	.	.	.	.	.	.	.	22	62	43	.	.
								34	66	63		
								37	66	58		
								72	66	67		
									67	70		
									67			
									Autumn	39		
									78			
									Autumn	66		
									78			
20	.	.	.	.	.	54	.	.	.	.	.	.
						69						
21	,	.	.	.	.	.	.	.	75	.	.	.
22	.	.	.	.	.	.	.	.	.	.	.	.
	6	6	4	3	4	6	1	8	12	15	5	4

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OF THE

ROYAL DUBLIN SOCIETY.

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Swimming Birds.

No.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	.	41	.	.	.	.	.	.	.	.	.	.
2	.	.	.	.	.	.	.	.	.	66	.	.
										66		
										66		
										66		
3	.	.	.	.	.	.	.	.	.	77	71	.
										77	71	
4	.	.	79	.	.	.	.	.	.	66	.	.
5	41	44	.	70	.	.	.	.	.	.	Winter.	37
	64			75								
6	63	.	.	.	.	.	.	.	.	.	.	.
7	.	.	.	.	.	.	.	.	.	.	79	.
8	.	.	.	.	.	.	.	.	.	.	.	.
9	.	.	.	.	.	.	.	.	.	.	.	.
10	65	.	.	.	.	.	.	.	.	.	Winter.	30
											Winter.	41
											Winter.	64
11	78	75	66	.	76	46	.	56	56	51	69	75
		76				47				67	75	77
						Summer	58	.	Autumn	53		79
											Winter.	35
											Winter.	41
											Winter.	51
											Winter.	65
12	.	.	70	.	53	.	.	.	.	.	Winter.	29
			70		53						Winter.	30
					53						Winter.	40
13	.	.	.	.	.	.	.	.	.	.	.	60
14	.	.	.	.	.	.	.	.	.	.	.	.
15	.	.	.	.	.	75	.	28	72	79	.	.
								73	76			
16	.	.	Spring.	50	.	.	.	.	.	.	.	.
17	.	.	.	.	.	77	.	74	.	.	Winter.	50
18	45	48	.	50	.	.	64	.	Autumn	64	.	.
		55										
19	.	.	.	.	.	.	.	22	62	43	.	.
								34	66	63		
								37	66	58		
								72	66	67		
									67	70		
									67			
									Autumn	39		
									78			
									Autumn	66		
									78			
20	.	.	..	.	.	54	.	.	.	.	.	.
						69						
21	.	.	.	.	.	.	.	.	75	.	.	.
22	.	.	.	.	.	.	.	.	.	.	.	.
	6	6	4	3	4	6	1	8	12	15	5	4

VI.—ON THE GEOLOGICAL STRUCTURE OF THE NORTHERN HIGHLANDS OF SCOTLAND; BEING NOTES OF A RECENT TOUR, BY EDWARD HULL,

LL.D., F.R.S., DIRECTOR OF THE GEOLOGICAL SURVEY OF IRELAND.
PLATES 9, 10, AND 11.

[Read, December 20th, 1880.]

The following notes were made during a tour in the North Highlands of Scotland during the spring of 1880, under the guidance of Professor Geikie, Director of the Geological Survey of Scotland, in company Mr. R. G. Symes, of the Geological Survey of Ireland, and several other friends; the object being to observe the character of the geological formations of that district, with a view to a comparison with those of the north-west of Ireland, where the operations of the Survey are about to commence.*

The author could not hope to be able to communicate much information (if any) absolutely new, but the physical features and geological phenomena proved of such interest, and of so remarkable a character that he hoped a brief outline of his observations would not prove unacceptable.

The course taken was as follows:—Reaching the village of Garve, near Dingwall, by the Highland Railway, the road lay right across that part of Scotland to the head of Loch Broom and Ullapool, through the beautiful glens of Braemore, which open on the head of Loch Broom. Thence to Inchnadamff, which lies at the head of Loch Assynt, and close to the base of Ben More, Canisp, and Quenaig. Thence to Scourie and Rhiconich, which is only a few miles distant from Cape Wrath, and then across Scotland to Lairg, where the railway to the south was reached. By this route two traverses across the country, at a distance of about thirty miles from each other, were made, and the western coast for a distance of about fifty miles was examined.

The geological structure of this district has only recently been clearly and definitely demonstrated by the researches of the late

* This visit was an official one, made with the sanction of the Director-General.

Sir R. I. Murchison,* following on the discovery by Mr. Charles Peach, of Lower Silurian fossils in the Durness and Assynt limestone (1854). Previous to that period the crystalline schists of the Central Highlands were considered to be of "primary" age; and the red sandstones and conglomerates of the north-west coast were supposed to be of the same geological age as those of the north-east coast—namely of "Old Red Sandstone" age.

Sir R. I. Murchison demonstrated that the red sandstones and conglomerates of the west lie beneath all the crystalline schists, quartzites, and limestones of the Central Highlands, to which they are unconformable,† and as the latter are shown, by the fossils found in the Assynt (or Durness) limestone, to be of Lower Silurian age, the underlying sandstones are inferred to be representatives of the Cambrian, and the fundamental gneiss and schists, which underlie the Cambrian, are also inferred to be representatives of the Laurentian group of Canada, which lies at the base of the Cambrian and Silurian rocks of that country.

The general section may be stated as follows :—

Formations of the Northern Highlands.

Lower Silurian Beds, probably from 7,000 to 10,000 feet.

	Approximate thickness in Feet.
(*a.*) Gneiss, quartzite, mica-schist passing down into the Upper Quartzite of Benmore in Assynt, . (over)	5,000
(*b.*) Ribband glossy slates and flagstones, . . (about)	500
(*c.*) Assynt limestone—upper part yellowish and dolomitic in places; lower white, and full of cavities like casts of fossils, but rarely with fossils themselves, . .	100 to 1,000
(*d.*) Ferruginous sandy flags, shales, and bands of limestone, containing "fucoid" markings, ...	100 to 200
(*e.*) Lower Quartzite; purple, grey, and white quartzite, the upper beds penetrated by annelid burrowings, .	500 to 1,000
(Great hiatus and unconformity.)	

Cambrian Beds.

Red and purple sandstone, sometimes pebbly, and towards the base passing into a conglomerate, with large pebbles and blocks of quartz, quartzite, jasper, felstone, gneiss, &c., in thickness from	0 to 3,000

* Quart. Journ. Geol. Soc., London, vols. xv. and xvii., 1858-61.

† "Siluria," 4 Edit., p. 163, with section p. 169. Figures of the fossils are given by Murchison; they consist of Maclurea, Ophileta, Oncoceras, and Orthoceras.

Laurentian Beds.

(*a.*) Upper part; hornblende schist, hornblende gneiss, and hornblende rock, sometimes micaceous, and penetrated by quartz veins, ...	Of great but uncertain thickness (*over* 20,000 *feet.*)
(*b.*) Lower part; reddish gneiss, penetrated by veins of granite or "pegmatite,"	

The above may be regarded as the general succession of the rocks about Loch Assynt, and as far as Loch Broom towards the south, and Loch Laxford towards the north.

It need hardly be stated that within this compass the beds vary much in thickness;—but not in character.

Throughout this region, and as far as the shores of Loch Dow, the Cambrian beds often rise into isolated precipitous hills or break off in grand escarpments and precipices, formed of nearly horizontal beds, rising tier above tier to elevations of 3,000 feet or upwards. Amongst the most remarkable is the north shoulder of Quenaig (Plate IX., fig. 3), which rises in the form of a great terraced buttress of red sandstone, its sides cut into deep gullies by mountain torrents, and accessible only by stiff climbing. The western shoulder of Suilven, as seen from the banks of the ferry at Kylesku, the remarkable escarpment of Benmore Coygeagh, (Plate IX., fig. 2), and the isolated truncated pyramid of The Stack (Plate IX., fig. 1), are all instances of the results of denudation, acting upon masses of horizontally bedded sandstone, in producing bold and massive scenery—differing in character from that of any of the formations either above or below.

On reaching the Inn of Aultguish we came in sight of the mountains of Cambrian sandstone, at a distance of about ten or twelve miles to the westward, seen through a gap in the schistose rocks, and rising above Loch Broom in massive terraces; the horizontal stratification being clearly discernible by the aid of the binocular glass. The winter's snows still lingered on the summits and on the surfaces of the upper terraces. In front of them were the quartzite mountains of Ben Dearig and the neighbouring heights, generally capped with snow, which rise in bold rounded masses to an elevation of 3,551 feet.

On descending towards the head of Loch Broom, along the valley of Braemore, we visited one of the most remarkable river gorges in the British Isles—a veritable

miniature cañon (Plate X., fig. 6), hewn by the mountain torrent out of slightly inclined beds of quartzite. Crossing on to a pretty little suspension bridge, thrown across the gorge by Mr. Fowler, C.E., 60 feet in width, we looked down on the bed of the stream below, at a depth of 222 feet—that is, over three and a half times the width of the chasm at the spot where spanned by the bridge. We could follow with our eyes the chasm for a considerable distance above and below the bridge—the sides bounded by nearly vertical walls of quartzite, decorated with a natural growth of ferns, shrubs, and climbing plants—to the rapids by which the torrent descended from a loch situated higher up the glen. Looking down the stream, the chasm could be followed for about a mile before it opened out on the wide glen of Braemore.

This miniature cañon is itself situated in a much wider valley, bounded by mountains of quartzite, and in excavating it the stream has been facilitated in its operations by numerous nearly vertical joints, represented in Plate X., fig. 6, traversing the beds of quartzite in the direction of its course, as well as by smaller joints and fissures crossing these at obtuse angles.

On descending along the shore of Loch Broom, we observed the horizontal beds of Cambrian sandstone, about 3,000 feet in thickness, appearing from below the inclined beds of quartzite on the southern banks; and at the bridge of Ault Corry crossing a burn, about a mile from Ullapool, we had an opportunity of examining the "Assynt limestone," here only ten feet in thickness, for the first time, (Plate X., fig. 7).* Just outside of Ullapool we passed a bluff, showing the superposition of the lower quartzite on the red sandstone and conglomerate of the Cambrian formation, with a clear unconformity in the stratification. We had thus in our first day's journey made a transverse section of the Lower Silurian metamorphic series of the Northern Highlands. It seemed clear to us that notwithstanding some slight fissures, some faulting, and possibly local foldings or inversions, we had traversed a gradually descending series of highly metamorphised beds of quartzite, gneiss, and schist, down to less highly altered beds in contact with the Cambrian, inasmuch as the Assynt limestone and the associated shales and flagstones could scarcely be recognised as having undergone metamorphic action. This was pointed out to

* Murchison and Geikie, Quart. Journ. Geol. Soc., vol. xvii., p. 184.

us by Professor Geikie, and was readily acknowledged by his fellow travellers.

On the second day our route from Ullapool to Inchnadamff, a distance of twenty-six miles, lay along a tract of country bordering the Silurian and Cambrian formations. We passed under several grand escarpments of Cambrian sandstone; the most remarkable being that of Benmore Coygeagh (Plate IX., fig. 2), which faces the south, and terminates abruptly on the side next the ocean. The cliffs of horizontal sandstone rise to a height of about 3,000 feet, and are worn into deep gullies by the action of torrents. Nevertheless, the face of the escarpment rises like a great wall of red sandstone from the crest down for a thousand feet, where the slopes commence. A short distance further north we came in view of "The Stack," an isolated mass of Cambrian sandstone, (Plate IX., fig. 1) also in horizontal beds; and, beyond, the heights of Coulmore* and Coulbeg, the former capped by the lower quartzite of the Lower Silurian series.

Throughout this tract the "Durness Limestone" became more and more conspicuous as we proceeded northwards; its thickness increased till, on approaching the head of Loch Assynt, it expanded to about 1,000 feet, and rose in a conspicuous escarpment above the foot of the quartzite slope at the eastern base of Canisp. The presence of the limestone amongst the hills and valleys is marked by a band of verdure in the midst of the sterile tracts of heather formed by the quartzites both above and below. The limestone is generally weathered as white as chalk, but in some places contains beds of dolomite weathering rusty brown. It is but very slightly altered, and frequently contains cavities exceedingly like those left by fossil shells; but with the exception of an *Orthis* (?) found by Mr. Symes, we did not succeed in obtaining a single specimen of organic origin.

On approaching Inchnadamff we skirted the eastern base of Canisp. This is an escarpment of Cambrian sandstone capped by quartzite, rising in a grand mural cliff facing the Atlantic. It terminates abruptly along the shore of Loch Assynt, and from the north shore of the loch the whole structure of the mountain is clearly revealed. The lower quartzite is seen to descend with a

* Coulmore, together with Canisp and Suilven, are represented in one of the illustrations in Murchison's "Siluria," 4 Edit., p. 170; and are graphically described by Hugh Miller.

gentle slope across the truncated horizontal beds of Cambrian sandstone till the latter is cut out altogether, and the base of the Lower Silurian series rests directly upon the Laurentian gneiss.* The section (Plate XI., fig. 9) taken across Quenaig, on the north shore of Loch Assynt, shows a similar structure amongst the formations.

This disappearance of the Cambrian beds as we proceed northwards is a remarkable feature in the physical geology of the district. The abrupt truncation of the sandstone at the edge of the Silurian quartzite, leaves no doubt that the formation was enormously denuded, even before the Lower Silurian beds began to be formed. At that period, however, the beds were tilted towards the west. Their present horizontal position being in consequence of the tilting towards the east of the Silurian beds.

On approaching the deep inlet called Loch Dhu (or Dow) and the ferry of Kylesku, we passed near the base of the grand precipices along which Quenaig terminates towards the north. The bold bluffs of Cambrian sandstone rise about 2,000 feet, and form certainly the noblest cliffs I had seen (Plate IX., fig. 3.) Notwithstanding the great thickness of the formation (about 2,000 feet) in Quenaig, the whole had actually disappeared under our feet; and we could trace the Silurian quartzite margin resting directly upon the dark hornblendic schists of the Laurentian formation which extends from the base of Quenaig to the coast, and to the shores of Loch Dhu.

From Kylesku to Scourie our course lay over a tract of broken and comparatively featureless country, highly glaciated by an ice-sheet which had moved towards the Atlantic. The rocks belong to the Upper Laurentian series, are chiefly hornblendic, highly crystalline in structure, schistose, and gneissose; occasionally schist of bronze mica was observed. Quartz veins are of frequent occurrence, and the beds are slightly crumpled. These rocks we had a good opportunity of examining during our last excursion northwards, on the following day, when we drove from Scourie to Rhiconich, a distance of twelve miles, the whole over Laurentian rocks.

Our course lay over an exceedingly rugged country, with numerous little lochs, rock-basins, gullies, and deep ravines. Everywhere the rocks were exposed to view, presenting remarkably ice-worn surfaces, often strewn with boulders of quartzite and

* The scenery at the head of Loch Assynt forms the Frontispiece to "Siluria" 4 Edit.

of other rocks from the interior mountains. There is no mistaking the direction of the ice movement, which has here been westward; but it is only in protected spots that boulder clay, or moraine matter, is to be found. In general the rocks are bare to a remarkable degree, the ice having apparently swept the loose materials out into the ocean.

On this day we passed under Ben Stack (Plate X., fig. 4), a pyramid of dark Laurentian hornblendic gneiss, rising 2,364 feet above the sea, and the highest elevation (as I was informed by Professor Geikie) to which the Laurentian rocks rise on the mainland. We were also close under the escarpments of Ben Arkle (Plate XI., fig. 8) and Foinaven, the former 2,576 feet, and the latter 3,016 feet. These are formed of Laurentian beds, capped by Lower Silurian quartzite,—the whiteness of the latter contrasting with the dark tints of the former. As already stated, the Cambrian sandstones have been entirely denuded away over this part of the country previous to the deposition of the Lower Silurian beds. The section (Plate XI., fig. 8) may be compared with that across Quenaig (Plate XI., fig. 9), in order that the changes in the stratification and physical features may be better understood.

It should be observed that throughout the district we examined, the lower quartzite at the base of the Silurian series generally crops out as an elevated escarpment, towards the south, capping unconformably the Cambrian sandstone; towards the north, the Laurentian gneiss. As this escarpment crosses transversly the general drainage of the country, and the course of those rivers which rise in the interior and flow westward towards the ocean, it is intersected by deep and wide valleys, so that it is exceedingly broken, and the lines of cliff run far up the valleys towards the east. Coulmore, Canisp, Quenaig, Ben Arkle, and Ben Foinaven are all situated on the margin of the lower quartzite.

On the other hand, the upper quartzite rises into equal, or still higher elevations such as Ben Dearig, Ben More in Assynt, Ben Hee, and Meal Horn, and generally forms the watershed of the North Highlands. The Cambrian beds generally form isolated, or partly detached masses. In no district I have ever visited do the physical features give more clear expression to the geological structure than in the North Highlands of Scotland.

The Laurentian rocks extend all the way from Scourie to Rhiconich and Laxford Bay, and from thence to Cape Wrath.

On leaving Scourie, we pass transgressively over a descending series of hornblendic beds, sometimes micaceous, belonging to the upper part of the series. Sometimes the crystals of hornblende are here two inches in length. At Loch Naclaishfearn the beds are highly micaceous and garnetiferous. At the head of Loch Laxford we pass into the lower series, consisting of gneiss, well foliated, of red felspar, quartz and mica. Veins of pegmatite become more frequent as we proceed, and in crossing Laxford bridge, on the road to Rhiconich, fine sections are laid open in beds of gneiss penetrated by numerous dykes and veins of pegmatite (a kind of granite), consisting of red orthoclase, crystals of pale yellowish or grey oligoclase, often of large size and showing the fine parallel lines which characterize a triclinic felspar. Along with the above are quartz and green mica. The pegmatite veins traverse the gneiss and schists in all directions, sometimes vertically, at other times obliquely, and cross the planes of foliation. They have been noted by Murchison as characteristic of the Laurentian beds; but it is chiefly in the lower portion they become conspicuous. About Rhiconich, the dip of the beds is southwards or S. S. W., at various angles; and as this dip was more or less prevalent all the way from Scourie, I estimate that the Laurentian beds must be over 20,000 feet in this district;—how much more no one can say as the base never appears.

As we returned to Scourie by sea, we had an opportunity of surveying the coast cliffs of red gneiss, and had a fine view of Suilven, Canisp, and Quenaig towards the south, rising from a rugged plateau of Laurentian beds. The horizontal beds and terraces of red sandstone were easily discernible, even at the distance of over twenty miles.* The white dome of Ben More, and its adjoining quartzite ridges of Ben Arkle and Foinaven, bounded the horizon towards the west, while Ben Stack rose above the head of Loch Inchard (Plate X., fig. 4), which we were leaving behind, in the form of a dark shapely cone. Looking northwards over the heaving surface of the Atlantic we could see the islands of Ellen-a-Vullig in the direction of Cape Wrath.

On the day following (2nd June) we left Scourie and again crossed the North Highlands from sea to sea, reaching the rail-

* See View of these Mountains in Ramsay's Phys. Geol., Gt. Britain, 5 Edit., p. 288.

way at Lairg. The road lay along the valley of the Laxford, and by the banks of Loch Stack, Loch More, and Loch Shin, crossing the low watershed under Ben Hee. As far as regards this journey I have only to observe that we had an opportunity of observing the general succession of the beds from the lower quartzite upwards through the limestone series, the upper quartzite, into the metamorphic schists, and that, with occasional undulations in the stratification, there appeared to be a continually ascending series till we reached the granite of Lairg. Thus the results arrived at in reference to the succession of the beds between Scourie and Lairg were found to correspond with those arrived at by the more southerly traverse between Garve and Ullapool.

Do Pre-Cambrian beds re-appear in the Central Highlands? The question has been asked and answered in the affirmative by some geologists, "Do the Laurentian (or pre-Cambrian) rocks re-appear in the Central Highlands of Scotland after disappearing below the Cambrian sandstones and Lower Silurian quartzites of the western districts?" As far as the observations which we were enabled to make are calculated to throw light on the question, I can only state my own impression, that the evidence is against this view. Throughout the districts of Sutherland, Ross, and Cromarty which we visited, it was clear that the Laurentian beds must be buried at enormous depths underneath the Lower Silurian beds the further we proceed eastwards from the outcrop. It is quite possible that the whole of the Cambrian sandstones may be absent under the centre of the North Highlands. From the direction in which these rocks disappear through the effects of denudation, it was evident that even at a short distance below the upper quartzite they might be absent even when they were in greatest thickness at the western outcrop. The sections at Canisp and Quenaig are very suggestive of this. Therefore we may well suppose that under the centre of the North Highlands the Lower Silurian beds rest directly on a Laurentian floor; and it seems to me highly improbable (though possible) that these latter rocks reappear at the surface, as there is clearly an ascending series all the way from the west towards the east of that part of Scotland. In the above statement I only refer to the region north of the Caledonian canal. Until the geological survey of the Grampian range throughout the Inverness and Aber-

deenshire Highlands is completed, it will be impossible to affirm positively whether or not Laurentian beds actually reappear.*

The two Unconformities. Bearing upon the geological history of this region, there is nothing more remarkable than the occurrence of the two unconformities,—the lower, between the Laurentian and Cambrian beds, and the upper, between the Cambrian and Lower Silurian series.

Both of these are of the most trenchant description. The abrupt truncations, and the sudden change of characters in the beds lying on either side of the boundary lines, suggest long intervals of time and great changes in the physical conditions under which deposition took place.

In the first place, the Laurentian beds were metamorphosed, contorted, elevated out of the sea-bed, and denuded, before the Cambrian beds began to be spread over the uneven floor thus constructed. Professor Ramsay considers the Cambrian sandstones to be of fresh water or lacustrine origin,† and that glacial conditions were to some extent prevalent during their formation.‡ A large proportion of the pebbles and blocks found in the Cambrian beds is composed of fragments torn from the Laurentian masses.

Of the Cambrian formation it is clear that only a fragment now remains in the North West Highlands. Its base is often visible, but its original upper limit never. It bears evidence of the effects of at least two great denudations. The first before the deposition of the Lower Silurian beds; the second at a later period, probably often repeated, and coming down to recent times. The great buttresses of horizontal sandstone—against which the Lower Silurian beds rest—may be regarded as the eastern margin of continental land of the Lower Silurian period, embracing the outer Hebrides, and an unknown region beyond.|| At that period the Cambrian sandstones were tilted and the Lower Silurian beds

* The only rock resembling Laurentian which we noticed in the central districts was a remarkable massive red gneiss, at Inchbrae, seven miles from Garve, in a N. W. direction, on the Ullapool road. This gneiss consists of red felspar, black mica, a little quartz and epidote. As far as its composition is concerned, it might be of Laurentian age; but in position it appears to be high up in the Silurian metamorphic series.

† Phys. Geol. and Geog., Gt. Britain, 5 Edit., p. 285.

‡ Pres. Address, Brit. Assoc, Rep. 1880, p. 17. This view is founded on the discovery by Professor Giekie of glaciated surfaces of Laurentian rock passing underneath Cambrian sandstone at intervals all the way from Cape Wrath to Loch Torridon, together with large blocks of gneiss in the Cambrian bed.

|| Ramsay, Phys. Geol. and Geog., p. 87.

were in approximately horizontal positions. The case is different now, for the Silurian beds have an easterly dip, while the Cambrian sandstones are nearly always horizontal. It is clear, therefore, that the present horizontality of the latter is due to a second tilting in a direction opposite to the first. In the accompanying diagram (Plate X., fig. 5) I have attempted to restore the beds of the three formations to their positions at the time the Lower Silurian rocks were in their original horizontal position. It will be observed that *then* the Cambrian rocks had a dip westward, while the original denuded surface of the Laurentian schists sloped at a smaller angle in the same direction.* Upon this horizontality of the Cambrian beds depends in a large measure the peculiarities of the west Highland scenery, and it is doubtful if a stranger series of events in stratigraphical geology is to be found in any other part of the world.†

Do Laurentian Rocks occur in the North or West of Ireland? All that one can say at this moment is, that the district lying north of Galway Bay in Connemara, Belmullet in Mayo, and parts of north-west Donegal contain beds of gneiss similar in appearance and composition to those which constitute the Laurentian beds of Sutherlandshire, and that these beds stand in some sort of relationship to the recognized Lower Silurian metamorphic beds consisting of quartzites, limestones and schists. But until the Highlands of Donegal have been thoroughly explored by the officers of the Geological Survey, and the relations of the beds clearly established, no positive answer can be made to the above question, the Cambrian beds being (as far as we know) unrepresented.‡

* From this diagram, which was made at Quenaig (see Plate XI., fig 9), not being drawn strictly to scale, I cannot be certain that the slope of the Laurentian floor is correct.

† The peculiarities of this district have been described by Macculloch, Hugh Miller, Murchison, Ramsay, Geikie, and others.

‡ The author proposes to make a preliminary examination of the Donegal Highlands during the ensuing summer with a view to determine the question here raised.

REFERENCE TO PLATES.

Plate IX.

Plate IX. Fig. 1. This is a drawing of "The Stack," which, with its neighbours Coul Beg and Coul More, consists of nearly horizontal beds of Cambrian sandstone and conglomerate, resting on a floor of Laurentian schist and gneiss. The position of this isolated mass is inland from Lough Enard in Cromarty.

Plate IX. Fig. 2. Represents the grand escarpment of Benmore Coygeagh, in Cromarty, also consisting of horizontal beds of Cambrian sandstone, breaking off in precipices towards the south and west. The rocks of the foreground are of the same formation, and have an eastward dip. The view is taken from the shore of an inlet from Loch Broom, looking north.

Plate IX. Fig. 3. Represents the great buttress of Cambrian sandstone, in nearly horizontal layers, along which Quenaig ends off towards the north. From the base, the Laurentian floor from which the sandstone beds rise, stretches away northwards and westwards in a rough boulder-strewn tract to the shores of the Atlantic and the dark inlet of Kylesku. The manner in which the lower quartzite of the Silurian series stretches over the denuded edges of the Cambrian sandstones is represented in section, Plate XI., Fig. 9.

Plate X.

Plate X. Fig. 4. Ben Stack in Sutherlandshire, seen from the entrance to Loch Inchard. This is a remarkably symmetrical cone of Laurentian hornblende schist, rising 2,364 feet above the Atlantic. The bedding, as also the system of joint planes by which the rock is traversed, are clearly visible, and their relationship to the outline of the cone will be recognised at a glance. The shores of Loch Inchard are composed of the red gneissose beds underlying those of Ben Stack.

Plate X. Fig. 5. This is a diagram to illustrate the point to which I have drawn attention (p. 11), that at the time the Lower Silurian beds (s. 1) were being deposited in a nearly horizontal position, the Cambrian sandstone (c.) of the district around Loch Assynt must have had a westerly dip. Upon the upheaval of the former, and on its assuming an easterly dip, the Cambrian beds were placed in their present position of approximate horizontality.

Plate X. Fig. 6. Is a section, drawn to scale, of the deep gorge or cañon of Braemore, at the head of Loch Broom. The nature of this remarkable river-channel has already been sufficiently described.

Plate X. Fig. 7. The section at the Bridge of Ault Corry, near Ullapool, in which the following beds in descending order are seen—all of the Lower Silurian series:—

S. 5.—Hard, massive, reddish pebbly grit at the base of the upper quartzite—6 feet thick.

S. 5^1.—Whitish quartzite in regular beds—4 feet thick.

S. 4.—Thin band of shale and flags.

S. 3.—Limestone in several beds with bands of shale—6 to 10 feet.

S. 2.—Grayish sandy shale with fucoid markings.

S. 1.—Upper beds of lower quartzite.

General dip, E.S.E. at 5 to 6 degrees.

Plate XI.

Plate XI. Fig. 8. Section taken across Ben Stack and Ben Arkle. The former 2,364 feet, the latter 2,576 feet in elevation; direction about W. to E.

Ben Stack, as already stated, is formed of dark hornblendic schists, &c., of Laurentian age (L), penetrated by granite or pegmatite veins. The Cambrian sandstone being here absent, the Laurentian beds are immediately overlaid by the lower quartzite (s. 1) of the Lower Silurian series, forming the escarpment of Ben Arkle; this is followed by ferruginous sandy shales, with fucoids (s. 2), then by the Assynt limestone (s. 3), the glossy slates and flagstones (s. 4), the upper quartzite (s. 5), and finally by the micaceous schists of the interior (s. 6), at the margin of which the section ends.

Plate XI. Fig. 9. Section drawn across Quenaig, 2,240 feet, and Ben More in Assynt, 3,281 feet, and passing a short distance to the north of Inchnadamff. This shows the basement hornblendic schists of Laurentian age (L), overlaid by Cambrian sandstone and conglomerate (C), the beds of which are truncated along the eastern side of Quenaig by the lower quartzite of the Lower Silurian series. The succeeding beds are lettered and numbered as in the preceding section.

VII.—CORK ROCKS, BY G. H. KINAHAN, M.R.I.A., &c.

[Read, December 20th, 1880.]

When describing the Cork Rocks in the fourth chapter of the "Geology of Ireland," I pointed out that the Carboniferous rocks north of an irregular line drawn from Kenmare, county Kerry, to Passage West, Cork Harbour, have different relations to the underlying "Glengariff Grits" (Jukes) from those that are found to exist between the "Carboniferous Slate" and the "Glengariff Grits" (Jukes) south of this line; for while in the latter case there is a continuous sequence between the two, north of the line a similar sequence has nowhere been found.

On the north side of this line the proximity of the Carboniferous Limestone to the "Glengariff Grits" (Jukes) was pointed out by Griffith, Jukes, and their assistants, while the recent researches of Mr. M'Henry seem to prove that there is an undoubted unconformability between the older and newer strata. He has not, however, brought forward any evidence which proves an unconformability between the Carboniferous Slate of S. W. Cork and the "Glengariff Grits" (Jukes). On the contrary, all his work would seem to prove that Griffith and Jukes were right in stating that there was no unconformability or hiatus between these two groups of strata.

The reason for the unconformability between the Carboniferous rocks north of the previously mentioned line and the "Glengariff Grits" (Jukes) is a subject which as yet has not been properly considered or investigated, at first the problem may appear complicated, but if similar phenomena in action at the present day in different places are studied, the difficulty in a great measure disappears.

In north Europe, Scandinavia divides the Baltic from the seas to the westward. East of Scandinavia the sea bottom for a long period has been continually rising and sinking, while west of Scandinavia the sea bottom has been comparatively stationary. Consequently in the first area the different accumulations ought

to be more or less unconformable to one another, while in the latter all the strata should form a continuous sequence, and in the straits connecting the two sea areas, various complications partaking of the nature of the two different systems of accumulations might be represented.

Let it be supposed that a similar state of things to that now going on in the Scandinavian seas gradually had been in existence in the area now represented by Cork and the adjoining portions of Kerry and Waterford. *First,* the rocks now represented by those called by Jukes "Glengariff Grits,"* were accumulated over a large area. *Second,* along an irregular line from Dingle Bay to Kenmare, and thence to and beyond West Passage, Cork, a mass of country began to rise, and in connexion with it a spur of country extending from this line at Mangerton eastward for some distance. *Third,* in the area southward of the rising tract last mentioned the ground was stationary or gradually sinking so as to allow successive strata to accumulate on it; while northward of the rising ground, the land had already been rising before the accumulation of any new strata. *Fourth,* south of the irregular line the accumulations formed a continuous sequence, while northward of it including the tracts north and south of the spur of land extending eastward from Mangerton, the newer accumulations would lie more or less unconformably on the older. *Fifth,* east of about the longitude, of Cork, at the *hinge line* where the elevation adjoined the depression, there would be considerable complications, the accumulation of the two types being mixed and dovetailing into one another.

If the above suggestions are correct, northward of the line of rise, the newer rocks of the central Ireland Carboniferous type, ought to lie unconformably on the older in the following localities, viz., in the vicinity of Dingle Bay, at Killarney lakes, in the valley of the Flesk and Blackwater, at Kenmare, and in the valley of the Lee at Macroom, Coachford, Innishcarra, Blarney, and Passage West.

The localities just mentioned, beginning to the northward, give the following:—In the promontory of Dingle the Upper or

* It is necessary, for the sake of distinction, to connect Jukes' name with this group of rocks, as Prof. Hull has given a nearly similar name to a more extensive group of which these rocks form but a part.

Carboniferous Old Red Sandstone lies unconformably on the "Dingle beds," the representative of a portion of Jukes' "Glengariff Grits;" while south of Dingle Bay, between Doulus Head and Killarney, there seems to be a somewhat similar unconformability. In the neighbourhood of the middle lake of Killarney, in Glenflesk, and in the western portion of the Blackwater Valley, there is the great fault with a downthrow to the northward, but at the same time the Carboniferous rocks appear to be much nearer to the "Glengariff Grits" (Jukes) than they ought to be, if a regular sequence intervened between them; as, however, in the places where the sections are best exposed, the rocks evidently lie in inverted folds, nothing positive can be said as to the original relations of one group to the other. Further southward at Kenmare, and in the valley of the Lee, the relations between the Carboniferous Limestone, and the red and bright coloured older arenaceous and argillaceous rocks are very remarkable. As pointed out in the Geological Survey Memoirs and elsewhere, some miles westward of Kenmare in the neighbourhood of Sneem and Kilmackilloge, respectively north and south of Kenmare River, there are the "Carboniferous Slate," the upper member of the sequence that extends downwards conformably into the "Glengariff Grits" (Jukes); but in the neighbourhood of Kenmare there is a conspicuous difference as red rocks, not to be found to the westward, or in the country to the S.W., suddenly make their appearance, and associated with them are the rocks called Lower Limestone Shale, and the Lower Limestone; these red rocks appear to lie conformably on the "Glengariff Grits" (Jukes), but it is questionable whether the Lower Limestone Shale and the Limestone lie conformably on them or not. Further eastward in the valley of the Lee, at Macroom, Coachford, Innishcarra and other places, the Carboniferous Limestone seems to lie nearly directly on the "Glengariff Grits" (Jukes). In these different places "Lower Limestone Shale" is associated with the Limestone, and in the maps it is generally represented as encircling the different masses of the latter, this, however, seems to me to be improbable, as the Lower Limestone Shale is essentially a littoral accumulation and consequently must have only accumulated in those portions of the different areas where the con-

ditions were favourable for its being deposited, such as shallow bogs and the like. In connexion with these outliers of Carboniferous Limestone "Lower Limestone Shale," *in situ*, has been observed in places, but in others no trace of it can be seen, and apparently it is altogether absent, the limestone lying directly on the older rocks.

The rocks in the valley of the Lee, would seem to suggest a solution of the difficulty at present felt in reference to the difference in the arrangement of the rocks north and south of the previously mentioned irregular line between Kenmare and Passage West (Cork Harbour), as hereabout the newer rocks evidently were deposited in a valley margined with high cliffs of "Glengariff Grits" (Jukes); but the rocks in the Kenmare valley are so peculiar that before offering an opinion on them they would require a very careful examination.

In the vicinity of Cork Harbour, is the locality of the *hinge line*, between the depression and elevation where the rocks of *the Central Ireland type*, and of *the Cork type*, meet and intermingle. Consequently from Cork Harbour eastward to the sea near Dungarvan, the rocks in the sections may be of either types, or of the two types mixed up together, while in places they seem to lie unconformably on the "Glengariff Grits" (Jukes).

The "Glengariff Grits" also seem to be changing eastward, and I suspect that the rocks of the Commeragh mountains (conglomerates, &c.), although lithologically different, yet eventually will be found to be the littoral accumulations of the "Glengariff Grits" (Jukes).

VIII.—ON THE PHYSICAL UNITS OF NATURE,* BY G. JOHNSTONE STONEY, D.SC., F.R.S., SECRETARY TO THE SOCIETY.

[Read, February 16th, 1881.]

When mathematicians apply the sciences of measurement to the investigation of Nature, they find it convenient to select such units of the several kinds of quantity with which they have to deal as will get rid of any coefficients in their equations which it is possible in this way to avoid. Every advance in our knowledge of Nature enables us to see more distinctly that it would contribute to our further progress if we could effect this simplification not only with reference to certain classes of phenomena, but throughout the whole domain of Nature.

Hitherto the practice of mathematicians has been governed by the demands of the science of mechanics, in the greater part (though not in the whole), of which science it is possible to derive the units of all the other kinds of quantity from any three which may be chosen. A system built in this way upon a foundation which is arbitrarily assumed is necessarily an artificial system. The units which are usually selected as the fundamental units of a series of arbitrary systematic measures, are—

The metre† for lengthine, or unit of length,
The gramme for massine, or unit of mass, and
The solar second for timine, or unit of time.

These three, and all the units which may be derived from them may be called the metric series of units, and in this investigation they will be represented by small letters. Thus—

The fundamental metric units being,

l_1, the metre, the metric lengthine, or unit of length.
t_1, the solar second, the metric timine, or unit of time.
m_1, the gramme, the metric massine, or unit of mass.

some of the derived units will be,

v_1, the metric velocitine, or, unit of velocity, which is a velocity of one metre per second.

* This paper was read before section A., of the British Association at the Belfast Meeting in 1874.

† Since this paper was written the centimetre has been suggested as a unit of length, and has been largely made use of.

f_1, the metric forcine, or unit of force, which is the Hyper-decigramme,* this being the force which if it acted in a fixed direction on a mass of one gramme for a second would in that time change its velocity by one metre per second.

μ_1, the metric unit of the coefficient in the expression $\mu\frac{mm'}{r^2}$ for the gravitation of two masses towards one another. This unit is the coefficient which should be used if each gramme mass attracted other ponderable matter at a metre distance with such intensity as would impress on it an acceleration towards the attracting gramme of one metre per second per second.

e_1. the electromagnetic electrine, or the electromagnetic unit quantity of electricity in the metric series, is that quantity of each of the two kinds of electricity which must be discharged every second in opposite directions along a wire, in order to maintain in it the metric unit current; this currentine or unit current being defined as the current which must exist in a wire a metre long in order that it may exert a force of a Hyper-decigramme on ponderable matter at a metre distance charged with a unit of magnetism; and the unit charge of magnetism of either kind being defined as that quantity which acting on ponderable matter at a metre distance, charged with an equal quantity of magnetism, exerts on it the unit force, that is one Hyper-decigramme.

* The hyper-decigramme means the gravitation or downward force towards the earth of a mass which exceeds a decigramme in the ratio of $\frac{10}{g}$ where g is the acceleration of gravity measured in metres per second per second. The appropriateness of the term *hyper*-decigramme arises from the circumstance that the coefficient $\frac{10}{g}$ *everywhere* exceeds unity, whether within the earth, outside it, or on its surface; and the convenience of the term arises from the circumstance that *on the earth's surface* the coefficient nowhere exceeds unity by more than a small fraction, so that the hyper-decigramme is a force which but little differs in value from that gravitation or weight of a decigramme with which we, inhabitants of the earth, have become familiar; so that the name suggests *to us* the *amount* of the force. Gravitation is the downward force and gravity is the downward acceleration towards the earth as *observed*. They are chiefly due to the attraction of the earth, and in a small degree, when the observation is made on or within the earth, to the earth's rotation. This is the meaning of the word gravity as it is used by the classical writers on mechanics, (see Pouillet's Mécanique, *passim*), and the practice of some modern writers, who use this term to designate a force instead of an acceleration, is to be deprecated.

It is easy to ascertain the relation of this metric electrine to the B.A. (British Association) standards for electrical measurement, which are those most in use. The B.A. units are electromagnetic units based on the following fundamental units—the second for unit of time, the metre-seven (the quadrant of the earth, or 10^7 metres) for unit of length, and the eleventh-gramme (or gramme divided by 10^{11}) for unit of mass. These were so chosen as to furnish a connected body of systematic units with such values that the practical electrician could conveniently use them. Now the 'dimension' of electromagnetic quantity of electricity is $[\sqrt{\mathrm{LM}}]$ (see B.A. Report for 1863, p. 159).* Hence and from the foregoing values of the lengthine and massine of the B.A. series—

$$e_1 : \text{One Ampère} = 1 : \sqrt{\frac{10^7}{10^{11}}}$$

Therefore $e_1 = 100$ Ampères.

The term Ampère is here used to designate the B.A. unit of quantity, corresponding to the Ohm (the B.A. electromagnetic unit of resistance), the Volt (the corresponding unit of electromotive force), the Weber (unit of current), and the Farad (unit of capacity). The *electrostatic* units of the B.A. series might with great advantage be called the static-Ampère, static-Ohm, static-Volt, and static-Farad.

Units like the above, whether of the metric or of the B.A series, of which three are fundamental and all others derived from them in such a way as will exclude unnecessary coefficients from our equations, are called systematic units. In forming the existing artificial series of systematic units it has been usual to regard the units of length, time and mass as fundamental and the rest as derived, but *there is nothing to prevent our regarding any three independent members of the series as fundamental and deriving the others from them.* It is the aim of the present paper to point out that Nature presents us with three such units; and that if we take these as our fundamental units, instead of choosing them arbitrarily, we shall bring our quantitative expressions into a more convenient, and doubtless into a more intimate, relation with Nature as it actually exists. I will then approximate

* This follows at once from the fundamental equations of electromagnetism, viz.:—

$$\mathrm{F} \propto \frac{\mathrm{EE}'}{r^2}, \quad \mathrm{E} \quad \mathrm{C}t, \quad \mathrm{F} = \frac{\mathrm{C}l\mathrm{M}}{r^2}, \quad \mathrm{F} = \frac{\mathrm{MM}'}{r^2}.$$

to the values of the units of length, time, and mass, belonging to this which is a truly natural series of physical units.

For such a purpose we must select phenomena that prevail throughout the whole of Nature, and are not specially associated with individual bodies. The first of Nature's quantities of absolute magnitude to which I will invite attention is that remarkable velocity of an absolute amount, independent of the units in which it is measured, which connects all systematic electrostatic units with the electromagnetic units of the same series. I shall call this velocity V_1. If it were taken as our unit velocity we should at one stroke have an immense simplification introduced into our treatment of the whole range of electric phenomena, and probably into our study of light and heat.

Again Nature presents us with one particular coefficient of gravitation, of an absolute amount independent of the units in which it is measured, and which appears to extend to ponderable matter of every description throughout the whole material universe. This coefficient I shall call G_1. If we were to take this as our unit of coefficients of attraction, it is presumable that we might thereby lay the foundation for detecting wherein lies the connection which we cannot but suspect between this most wonderful property common to all ponderable matter, and the other phenomena of nature.

And, finally, Nature presents us in the phenomenon of electrolysis, with a single definite quantity of electricity which is independent of the particular bodies acted on. To make this clear I shall express "Faraday's Law" in the following terms which, as I shall show, will give it precision, viz.:—*For each chemical bond which is ruptured within an electrolyte, a certain quantity of electricity traverses the electrolyte, which is the same in all cases.* This definite quantity of electricity I shall call E_1. If we make this our unit quantity of electricity, we shall probably have made a very important step in our study of molecular phenomena.

Hence we have very good reason to suppose that in V_1, G_1, and E_1, we have three of a series of systematic units that in an eminent sense are the units of Nature, and stand in an intimate relation with the work which goes on in her mighty laboratory.

The approximate values of V_1 and G_1 are known, and I will presently endeavour to evaluate E_1. V_1 has been variously de-

termined by experiment as 3·10 metre-eights per second, 2·82 metre-eights per second, 2·88 metre-eights per second and may be assumed to be not far from 3 metre-eights per second. Accordingly we may put—

$$V_1 = 3 \text{ VIII. metres per second} \ldots\ldots\ldots (1).$$

Similarly, if we use the value given by Sir John Herschel for the mass of the earth, viz., 5942·XVIII* english tons, which = XXIV. grammes, we find that—

$$G_1 = \frac{2}{3} \frac{1}{\text{XIII}} \mu_1 \ldots\ldots\ldots (2).$$

To determine E_1, we must first establish a relation between the gaseous molecule of a body, and what in chemistry is called its atom. To do this, let us start with the definition that a *chemical atom* is the smallest mass of each kind of ponderable matter that *has been found* to enter or leave a combination. Now from Boyle and Charles's law we know that in all gases there are approximately the same number of molecules per litre, if they be taken at the same temperature and pressure; from experiments on diffusion we know that these molecules are alike in mass; and from the phenomena of chemistry we know that they are alike in other respects.

Let, then, a litre of hydrogen and a litre of chlorine be mixed and exploded, and let the resulting hydrochloric acid gas be brought back to the original temperature and pressure. It is then found to measure two litres. Hence, if N be the number of molecules in a litre of gas at that temperature and pressure, we learn by this experiment that N molecules of hydrogen, and N molecules of chlorine produce 2N molecules of hydrochloric acid. Hence, and since the molecules within each gas are alike, each molecule of hydrochloric acid must contain the quantity of hydrogen represented by a semi-molecule of hydrogen gas, and the quantity of chlorine represented by a semi-molecule of chlorine gas. We are thus introduced to the semi-molecule of each of these gases as a quantity which enters into combination; and as no other experiments suggest a smaller quantity, the semi-

* The Roman figures following a number stand for cyphers. Thus 3.VIII signifies 3×10^8, and 5942 XVIII stands for eighteen cyphers following 5942. Where no number precedes the Roman figures, the number 1 is to be understood, so that in XXIV. grammes, the Roman figures stand for 1 followed by 24 cyphers, in other words for 10^{24}, a number which may conveniently be called the Unit-twenty-four.

molecule of hydrogen, and the semi-molecule of chlorine, are, in the present state of science, to be accepted as the chemical atoms of these substances. Hence we may write—

H, the atom of hydrogen = the semi-gaseous molecule of hydrogen, and

Cl, the atom of chlorine = the semi-gaseous molecule of chlorine,

and we see that HCl is the proper formula for hydrochloric acid. We may further deduce from the observed densities of the gases that the masses of the atoms of hydrogen, chlorine, and Hydrochloric acid are to one another in the ratio of 1, $35\frac{1}{2}$, $36\frac{1}{2}$.

Another experiment shows us that a litre of steam may be resolved into a litre of hydrogen and half a litre of oxygen at the same temperature and pressure; in other words, that N molecules of steam are formed of N molecules of hydrogen and $\frac{N}{2}$ molecules of oxygen. Hence each molecule of steam contains a whole molecule (or two atoms), of hydrogen, and a semi-molecule of oxygen. We thus arrive at the semi-molecule of oxygen as a quantity that enters into combination, and as all other experiments with oxygen concur, the semi-molecule of oxygen is to be received as its atom, and H_2O is the proper formula for what is both the gaseous molecule and the atom of water. From the densities we may also deduce that sixteen is the atomic weight of oxygen, *i.e.* that an atom of oxygen is sixteen times as heavy as an atom of hydrogen.

Similarly from the densities of ammonia and of its constituents we learn that the atom of nitrogen is the semi-molecule and that the mass of its atom is 14 times that of hydrogen.

It must not be assumed that the atom is always the semi-molecule. In some cases it is found to be the entire molecule, and in other cases the quarter molecule. Thus the mercuric compounds of mercury give vapours of the same bulk as the vapour of the mercury they contain, and indicate an atom of mercury equal to its molecule, while the other volatile compounds of mercury contain more than one molecule of mercury in each molecule of the compound, and therefore do not disturb this conclusion. Again, a litre of phosphuretted hydrogen yields a quarter of a litre of the vapour of phosphorus and one and a-half

litres of hydrogen, indicating that the quarter molecule of phosphorus is its atom. The same is true of arsenic.

A similar treatment of marsh gas furnishes twelve as the mass of an atom of carbon, although carbon is not sufficiently volatile to enable us to ascertain the relation of its atom to its gaseous molecule.

By extending this method to all the available cases, we may deduce *from the fundamental properties of gases* a demonstration of a great part of the modern table of atomic weights, and of the doctrine of atomicity which depends on it. Thus, two bonds* are necessary to connect the group $S\,O_4$ with the two atoms of hydrogen that are united to it in sulphuric acid, while one bond is sufficient to join the atoms of hydrogen and chlorine in an atom of hydrochloric acid and so in other cases.

Now the whole of the quantitative facts of electrolysis may be summed up in the statement that A DEFINITE QUANTITY OF ELECTRICITY TRAVERSES THE SOLUTION FOR EACH BOND THAT IS SEPARATED. Thus, if a current pass in succession through vessels containing solutions of sulphuric acid and hydrochloric acid, two atoms of hydrochloric acid will be decomposed in the one vessel for each atom of sulphuric acid that is decomposed in the other, but *the number of bonds separated will be the same in both vessels.*

It is the quantity of electricity that passes per bond separated that we have now to determine, and this may be done approximately in the following manner. Several inquiries (see Prof. J. Loschmidt 'Zur Grösse der Luftmolecule' *Academy of Vienna*, Oct., 1865; G. Johnstone Stoney on 'The Internal Motions of Gases' *Phil. Mag.* August, 1868; and Sir William Thomson on 'The Size of Atoms' *Nature*, March 31, 1870), have led up to the conclusion that the number of molecules in each cubic millimetre of a gas at atmospheric temperatures and pressures is somewhere about a unit-eighteen (10^{18}). Hence the number of molecules in a litre will be about a unit-XXIV. Now, a litre of hydrogen at atmospheric pressures, and temperatures weighs, roughly speaking, a decigramme. Hence the mass of each molecule of hydrogen is a quantity of the same order as a

* The word bond is here used of the *connexions* between atoms when they enter into combination. When we employ the term in this sense, which seems its proper signification, bonds are to be distinguished from the hands or feelers which each atom has, and which by grappling with the hands or feelers of other atoms establish bonds between them.

decigramme divided by a unit-XXIV, *i.e.* a XXVth gramme. The chemical atom is half of this. Hence the mass of a chemical atom of hydrogen may be taken to be somewhere about half a twenty-fifth-gramme. There is no advantage in retaining the coefficient half in an estimate in which we are not even sure that we have assigned the correct power of 10, and I will therefore, for the sake of simplicity, take the XXVth gramme as being such an approach as we can attempt to the value of the mass of an atom of hydrogen.

Now it has been ascertained by experiment that for every Ampère of electricity that passes ninety-two sixthgrammes, *i.e.* ninety-two millionths of a gramme of water, are decomposed (see B.A. Report 1863, p. 160). This water is the result of a secondary action in the voltameter, but that does not effect the present inquiry. Ninety-two VIth grammes of water contain about one Vth gramme of hydrogen, which is therefore the quantity evolved. The metric unit of electricity e_1 is 100 Ampères, and will therefore set free 100 Vth grammes of hydrogen, *i.e.*, one milligramme. Now it appears, from the last paragraph, that this quantity of hydrogen contains $\frac{\text{XXV}}{1000}$ atoms, *i.e.*, XXII. atoms. And as there is a bond ruptured for each atom of hydrogen set free, this is also the number of bonds broken. In other words the quantity of electricity corresponding to each chemical bond separated is

$$\text{E}_1 = \frac{1}{\text{XXII}} e_1 \quad \dots\dots\dots\dots\dots\dots (3).$$

Collecting our numerical results they are

$$\text{V}_1 = 3.\ \text{VIII, metres per second} \dots (1).$$

$$\text{G}_1 = \frac{2}{3} \frac{\mu_1}{\text{XIII}}, \quad \dots\dots\dots\dots\dots\dots (2).$$

$$\text{E}_1 = \frac{e_1}{\text{XXII}}, \quad \dots\dots\dots\dots\dots\dots (3).$$

$$= \frac{1}{\text{XX}} \text{Ampères} \dots\dots\dots\dots\dots\dots (4).$$

We have thus obtained approximate values in known measures for the three great fundamental units offered to us by Nature, upon which may be built an entire series of physical units deserving of the title of a truly Natural Series of Physical Units.

It now only remains to deduce the units of length, time, and mass belonging to this series. For this purpose we may use

dimensional equations. Remembering, as is well known, that the dimension of a unit of velocity is $\left[\frac{L}{T}\right]$, that of a unit of coefficients of attraction $\left[\frac{L^3}{MT^2}\right]$, and that of an electromagnetic unit of quantity $[\sqrt{LM}]$, we find from equations (1), (2), and (3) respectively, that

$$\frac{L_1}{T_1} = A \frac{l_1}{t_1} \quad \ldots\ldots\ldots\ldots\ldots\ldots (4).$$

$$\frac{L_1^3}{M_1T_1^2} = B \frac{l_1}{m_1t_1^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots (5).$$

$$\sqrt{L_1M_1} = C \sqrt{l_1m_1} \ldots\ldots\ldots\ldots\ldots\ldots (6).$$

in which L_1, M_1, and T_1 are used to designate the units of length, mass, and time in the 'Natural' series, while l_1, m_1, and t_1 represent the corresponding units in the metric series, viz., the metre, gramme, and second. A, B, and C also are used, for brevity, to stand for the numerical coefficients of equations (1), (2), and (3), viz. :—For the numbers 3 VIII, $\frac{2}{3}\frac{1}{\mathrm{XIII}}$, and $\frac{1}{\mathrm{XXII}}$.

Solving equations (4), (5), and (6), we find

$$L_1 = \frac{C\sqrt{B}}{A} l_1 \ldots\ldots\ldots (7).$$

$$T_1 = \frac{C\sqrt{B}}{A^2} t_1 \ldots\ldots\ldots (8).$$

$$M_1 = \frac{CA}{\sqrt{B}} m_1 \ldots\ldots\ldots (9).$$

Substituting for A and B their numerical values, and writing metre, second, and gramme, for l_1, t_1, m_1,

$$L_1 = C \frac{1}{3\sqrt{15}} \frac{1}{\mathrm{XIV}}, \text{ metres.}$$

$$T_1 = C \frac{1}{3} \frac{1}{3\sqrt{15}} \frac{1}{\mathrm{XXII}}, \text{ seconds.}$$

$$M_1 = C \; 3\sqrt{15} \; \mathrm{XIV} \text{ grammes.}$$

or, more simply, (inasmuch as 10 is sufficiently near to $3\sqrt{15}$ to be used instead of it in an approximation like the present)

$$L_1 = C \frac{1}{\mathrm{XV}} \text{ metres } \ldots\ldots\ldots\ldots\ldots (10).$$

$$T_1 = C \frac{1}{3} \frac{1}{\mathrm{XXIII}} \text{ seconds} \ldots\ldots\ldots (11).$$

$$M_1 = C \; \mathrm{XV} \text{ grammes } \ldots\ldots\ldots\ldots\ldots (12).$$

In obtaining these equations we have only used the numerical values of V_1 and G_1, which are known to a satisfactory degree of

approximation, and if we go no farther there will remain but one arbitrary member in the entire of the resulting series of systematic physical units.

If we also introduce the numerical value found above for C, which depends on E_1 and is less accurately known, we obtain the following actual values for these units of Nature.

$$L_1 = \frac{1}{\mathrm{XXXVII}} \text{ of a metre} \ldots\ldots\ldots (13).$$

$$T_1 = \frac{1}{3}\,\frac{1}{\mathrm{XLV}} \text{ of a second} \ldots\ldots\ldots (14).$$

$$M_1 = \frac{1}{\mathrm{VII}} \text{ of a gramme} \ldots\ldots\ldots\ldots (15).$$

or, in other words—

The natural unit of length approaches in value to the thirty seventh-metre, (*i.e.*, the metre divided by 10^{37}).

The natural unit of time approaches in value to one-third of the forty fifth-second, (*i.e.*, one-third of the second of time divided by 10^{45}); and

The natural unit of mass approaches to the seventh-gramme, (*i.e.*, the gramme divided by 10^7).

This appears the best attempt we can yet make to determine these remarkable units. In the series to which they belong all the electrostatic units will be identical with the corresponding electromagnetic units; all the forces of Nature that are known to obey the law of the inverse square, whether they arise from gravitation, electricity, or magnetism will be expressed without coefficients; and the chemical bond which seems to be the unit of concrete Nature is brought into its proper relation to physics.

Postscript.—Many persons find it difficult to conceive of G_1 as a unit. G_1 may be avoided and M_1 substituted for it, if M_1 be defined as a mass such that it attracts an equal mass at a distance with the same force with which two units of electricity as defined on p. 56 (*i.e.* each equal to E_1), would, if placed at the same distance asunder, act on each other. The three fundamental units of the Natural System will then be V_1, E_1, and M_1, from which all others are to be derived. This M_1 is the same as the M_1 of equation (15).

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IX.—ON BIRDS OBSERVED IN AMELIA COUNTY, VIRGINIA, BY PERCY E. FREKE.

[Read, February 21st, 1881.]

I HAVE lived altogether for six years in Virginia, about thirty miles south of Richmond, the capital, and during that time I have carefully observed and noted the habits of the resident and migratory birds of the district, verifying my observations, as far as possible, by securing specimens and preserving skins. The fact with which I have been most struck is the apparent total absence of so many species, which, from their known range, I consider I ought to have met with, and the rarity of others which I expected to have found more numerous. The period during which I have resided there, and the time and pains which I have given to the subject, preclude the possibility of a species frequenting in any numbers the district in which I have been working, without my being aware of it. Some birds, certainly, I have noticed which I have never been able to obtain, or to determine satisfactorily, and which are therefore omitted here; but they are not many. The distance at which I lived from the sea, or from any large river, must account for the absence of the host of waders and swimming birds, which a residence near the coast would have added to my list; but still, as there were two small rivers with swamps and ponds in the vicinity, which I constantly and carefully searched, I think I was justified in expecting a larger number of species than appear in the following paper. I can only suppose that many species having a widely extended range, are yet within that range, but local in their distribution, and that the district in which I lived was not a very favoured one in this respect.

To the study of migration I have given especial attention, noting first arrivals and last appearances. In autumn I wrote a list every evening of all the migratory birds I had observed during the day, and noted how one by one the different species disappeared.

Many species become unusually numerous for a short time before their departure, being reinforced, no doubt, by the northern contingent on its way southward. Others, with which Virginia

seems to form about the limit of their northern range, band together in some numbers for a day or two, and then abruptly disappear, as our own swallows may often be observed to do at home.

In migrating north the smaller birds generally arrive suddenly in some numbers, often in large flocks, which after a while scatter themselves over the country to breed, or wholly, or partially pass on to the north. At this time of the year fifty birds will probably be noticed for one that will be observed a few months later, although the bird population of the country is always pretty numerous. This is probably caused not only by the absolutely greater numbers which are present at the time, but also because they are much more conspicuous when collected together in flocks, or when the males, while seeking their mates, display themselves as much as possible; whereas, later in the year, when they have commenced the duties of the summer, they are scattered in pairs over the country, and seek concealment for themselves and for their young. The trees and bushes too are then in full leaf, and their dense shade affords the forest-loving species an almost impenetrable screen.

In travelling south again they generally come in small parties or families at first, then in numbers or in flocks, which may be met with everywhere for a while, and then disappear. Some, as the geese, appear in much larger flocks when going southward than when advancing to the north; whereas, with others, as the different species of Molothrus, Grackels, &c., the reverse is the case. Some, as the gold-crests, that I have observed assembled in small family parties, a little earlier in the year, in Canada and the Northern states, seem to visit us singly, or at the most in pairs, and during some years I have observed species appearing by no means uncommon, which in other years were totally absent.

Go into the pine woods late in the autumn and you may walk for half an hour without seeing anything of bird life; then you hear a note, and you see several little birds in the tree tops. Probably it was the Carolina tit that attracted your attention, for this restless little creature is generally the first to see you and give the alarm. If you remain still, you may perhaps see five or six species of birds busily searching for insects, and flitting restlessly from tree to tree, passing and crossing each other, but all

tending in one direction. You will probably see the Carolina and the tufted tit, one or two of the smaller woodpeckers, the white-bellied nuthatch, perhaps the gold-crested wren, and one of the small warblers, generally *Dendrœca coronata.* Busy as they are searching for insects, they all seem to keep together, and in a few minutes pass away; not one will remain, and the woods will be as silent as if there were no living thing for miles around. In an hour perhaps you may meet another little flock, acting just in the same way. In the spring you may see somewhat the same thing, but the flocks are smaller, and composed generally only of tits, and perhaps a couple of woodpeckers.

At first I was under the impression that in autumn these little flocks were all moving southward, but longer experience has convinced me that this is not the case, but that their regular migrating movements are performed, in most instances, during the night, and that in the daytime they devote themselves to searching for food, and move about the woods without any regard to the points of the compass, generally following the direction of the valleys or streams where veins of deciduous trees run through the forest of pines.

I have also often noticed a sudden incursion of some species not generally abundant. The locality where they are observed will now be alive with them, quarrelling, chattering and fussing about looking for food, moving on their course being apparently the idea furthest from their thoughts; perhaps another day may be spent by them in the same way, *at the same spot,* and on the next not one will be found in the district.

The migration southward seems to be performed more regularly and leisurely than when going north. In spring they will sometimes, with favourable weather, pass through in a great hurry, the bob-o-links, for instance, seldom staying more than two days or three. In other years they will often hang about for a long time, and a spell of bad weather will sometimes drive them away from the district entirely, to reappear when it is over, when they remain in varying numbers, occasionally for weeks, and that with species not one of which stays all the summer.

Partial migration, I think, also takes place to a very large extent, but is not so easily observed. For instance, the robins (*Turdus migratorius*), bluebirds, tits, and nuthatches, which we

see in winter, are not, I think, the same individuals which have remained and bred with us during the summer. The two former species migrate to a considerable extent during the daytime. In autumn I have constantly seen small flocks coming from the north. Like specks in the distance they come steadily on, the robins in little bands of from half a dozen to twenty; they light on a tree, and sit there apparently resting themselves for some time, then suddenly they all start again and fly off straight, as far as the eye can follow them, to the south. I have often timed the robins by my watch, and generally find they remain for ten minutes or a little more, but sometimes they will stay for half an hour. The bluebirds come in fewer numbers—from one or two to half a dozen. They do not fly so far at once, and generally alight on the very top of some tall tree, where they often stay scarcely two minutes, though sometimes they will remain a long time, generally incessantly uttering their call note.

Although I have noticed this form of migration in robins, yet I also observe that they, perhaps more than any other bird, are prone to appear suddenly in flocks in a particular locality, which they will frequent in great numbers for a few days, and then disappear, following what I believe to be the ordinary rule of migration among small birds.

Wild pigeons also migrate largely during the daytime; in comparatively small bands in spring, which often stop with us some time, but often in immense armies in autumn, which rarely halt.

The males of some birds, especially the warblers, often arrive before the females, and are sometimes quite numerous for some days before a single female has been seen. This is, perhaps, most markedly the case with the black-and-white creeping warbler.

Regularly every year, also, I have noticed that in the autumn migration southward, the localities frequented by some birds differ entirely from those which are sought by the same species when advancing northward in spring; this is notably the case with the pine warbler, as mentioned under the head of that species.

Although scarcely more than one hundred miles from the Atlantic, I have never, during all the time I have been there, seen a single gull, or truly saltwater bird in the district of which I write, even after the worst and most stormy weather, nor at any season of the year.

In Virginia I have noticed especially the tameness and familiarity of many species during the breeding season, some of which at other times of the year, are comparatively wild and unapproachable. This, I believe, is very commonly the case with birds generally, but I have never noticed it so markedly as I have there.

Turdus migratorius (Linn.) *American Robin.*—A few may be seen all through the winter, but they arrive in large flocks from the south early in March, when they collect in great numbers on the tree tops, chattering and screaming. The earliest note I have of their arrival is the 2nd of March. This was in 1878. They scatter themselves over the open ground in search of food, hopping about with a remarkably upright carriage. They are very fond of the berries of the cedar, and on the edges of the woods these trees are often covered with them, swarming about among the branches, and devouring the berries as fast as they can, fluttering and chuckling all the time in a most fussy manner. As evening draws on, or at the sound of a gun, they collect in flocks on the tops of the highest trees. A few pairs remain with us all the summer and rear their young, but most of them pass on to the north. They generally choose as a site for their nest a low tree near a house, or some open spot, and I have never found them building in the woods, as some of the thrushes do. The 12th October is the earliest date at which I have seen the flocks returning from the north, and they continue to pass on southward for some time. Their chuckling note reminds one much of our own blackbird, and their song is rather good.

Turdus pallasi (Cabanis.) *Hermit Thrush.*—This is a resident species, apparently not migrating even in the most partial manner; nor have I noticed it in any way more numerous at one season than another. It is a shy, retiring bird, and never seems to collect in flocks, but is met with singly or in pairs—generally the latter. It loves best the deep dark woods, where it builds its clay-lined nest in the fork of some cedar or dogwood bush, at the height of eight or ten feet from the ground, and there lays its blue eggs. It is rather a silent bird, gliding noiselessly through the trees, seldom rising to any height, and as evening comes on, frequently uttering its whistling note when it thinks itself unobserved; but I once saw it singing

vigorously in the sunshine, on the topmost boughs of a tall tree in an exposed situation.

Harporhynchus rufus (Cabanis.) *Brown Thrush.*—This fine songster, whose note always reminds me of our own thrush, arrives in spring; but whether a few remain all the winter or not, I am not sure. I have seen it as early as the 18th March, with snow on the ground, and a cold north wind, in very wintry-looking weather, but they do not become common for a month later. One generally sees it flitting about near the ground, among thick bushes. The nests I have taken have always been in situations of this kind, in thick tangled places. Its life is protected by law on account of its fine voice, but it has a very bad reputation for pulling up sprouting corn. It is in my opinion the best songster in Virginia, even the mocking bird cannot compete with it as a vocalist.

Mimus polyglottus (Boie.) *Mocking-bird.*—It is now a permanent resident, being found all through the winter, which formerly I am told was not the case. Although it builds, and spends its life, generally in the close vicinity of the homestead, I have always found it very distrustful about its carefully concealed nest, and prone to desert it on slight provocation. It is generally believed among the negroes, that if young mocking birds be confined in a cage, although the parent birds will feed them at first, and exhibit the greatest anxiety to procure them their liberty, yet when they find that this is impossible, they invariably bring them something which poisons them. Unfortunately I have never been able to decide this by experiment. As an imitator of the notes of other birds, and sounds with which it is familiar, it is certainly unequalled by anything I have ever heard, although in this respect some individuals are much more proficient than others. In listening to an accomplished mocking bird one hears the most vivid impersonation of the songs of many birds, the chirping of young chickens, the cry of the little sparrow-hawk, the twittering of a flock of partridges, followed by their frightened scream as a hawk dashes among them, this last performance is a great favourite with the mocking bird, who seems to enjoy dwelling upon a scene which he has probably often witnessed. Perhaps the nervous excitement, caused by the tragedy which he has beheld from the safe shelter of some thick

bush, has impressed it upon his mind. They are most pugnacious birds themselves, attacking and vanquishing every bird which frequents the neighbourhood of the house near which they have established themselves. In the Purple Grackle, however, they find more than their match, and the contest between them always ends in the defeat of the mocking-birds, and their expulsion from the vicinity. Although it is such a perfect mimic, yet as a vocalist I do not think it approaches to our own song thrush. It sometimes sings to itself at night, in a low, monotonous, dreamy sort of way, and several of them outside my window, have often thus kept me awake in the hot summer nights. Its life is protected by law, and its exportation from the State prohibited.

GALEOSCOPTES CAROLINENSIS (Caban.) *Cat-Bird.*—It arrives about the end of April. The earliest date I have seen it was on the 23rd, though I heard it squalling in the bushes late on the previous evening. They remain until autumn, and from every bunch of briars, and the bushes lining the streams, comes their absurdly kitten-like cry; and though they dive into the thickest part on the first alarm, they are not shy birds, but in half a minute or so, will come out and mew at you a few yards further off. They sing rather well, and are tolerably good imitators of the notes of other birds. They are protected by law.

SIALIA SIALIS (Band.) *Blue-Bird.*—There is something about this little bird which, though it differs so much in colour yet, strikingly reminds us of the English Robin. It is I believe a partial migrant, appearing in flocks in the end of February, and again in October; but they may be seen at any time of the year sitting on some post or twig, and flying to the ground now and then, to pounce on some grub or insect, and flitting down the fence from post to post in front, as one rides along the road. They breed early in spring, and generally lay their pale blue eggs in a hole in some decayed tree or post. They are protected by law.

REGULUS SATRAPA (Licht.) *Gold-Crest.*—This is a winter visitor. During some years I have found it not at all uncommon, and in others I have not seen a single specimen the whole winter. The earliest date I have observed its arrival has been the 2nd of December; but it is more common in January. It is generally found in pairs, frequenting chiefly deciduous timber, often alone

though sometimes in company with other small insectivorous birds.

POLIOPTILA CÆRULEA (Sclat.) *Blue-gray Gnat-catcher.*—The earliest note I have of its arrival is the 1st of April. I think the males come a little before the females. They remain until autumn, and build a beautiful, thick, felt-like nest, strikingly resembling that of the ruby-throated humming-bird, only of course larger; the rim, however, is not turned in as in the humming-bird's nest. I have sat, watch in hand, looking at it feeding its young, and found the same bird return about every two minutes; but insects were abundant, and it never had to go far—indeed, it was generally in sight all the time.

LOPHOPHANES BICOLOR (Bonap.) *Tufted Tit.*—This bird is very abundant, the most so I think of the Tit family, being found commonly all the year, but especially in spring and summer, arriving in numbers about the middle of February. In summer it is found chiefly among deciduous trees, in winter it seems to prefer the shelter of the pine woods. I have found it building in holes in trees, at some height from the ground. Its call-note is a clear whistle; its note of alarm resembles "is-is-ha is-ha-ah-ah."

PARUS CAROLINENSIS (Aud.) *Carolina Tit.*—It is a permanent resident, and common throughout the year, but still I believe a partial migrant. It very much resembles the English cole tit, both in habit, and general effect. It is a busy, fussy little bird, scolding and chattering at an intruder in its haunts, and busily searching for insects all the time. It generally selects for its nest some old deserted hole of the downy woodpecker, so common in decayed timber by the river sides.

SITTA CAROLINENSIS (Lath.) *White-bellied Nuthatch.*—Common throughout the whole year. In early spring their courtship is very amusing. I have seen as early as the 18th February, two or even more males, following one female, up and down the tree stems, and round and round, with their tails spread out to the utmost, and performing all sorts of strange antics; but I have never seen them fight for the possession of the fair one, as many birds do. Yet this nuthatch is by no means deficient in courage; for I have seen it attack a Blue-bird, who is generally well able to take care of himself, and snatch from it a large white grub

which it had caught, and to eat which at its leisure, it had flown to a tree on which the nuthatch was searching for insects.

Sitta canadensis (Linn.) *Red-bellied Nuthatch.*—On the 10th of January, during some very cold weather, with snow on the ground and the thermometer below zero, I noticed a pair of small nuthatches, whose cry was not familiar to me, fly across the road and light on a tree behind me. I followed them, and easily approached within a few feet. They remained for some time running over the boughs close above my head, and almost within reach, and were easily identified as the present species; but having no gun I was unable to secure one. This is the only occasion on which I have met this bird in Virginia.

Certhia familiaris (Linn.) *Brown Creeper.*—This is a winter visitor, and generally arrives rather late. I have never noticed it before the 22nd of December, nor have I seen it after the 5th of April. It is a solitary bird, being generally found singly, though sometimes in pairs. It is not very common, and seems to prefer large tracts of timber, to the trees round the homestead.

Troglodytes ludovicianus (Bonap.) *Carolina Wren.*—It is very common all the year, and does not seem to migrate even locally. Its song of "dear-wife, dear-wife," may be heard at almost any season of the year, on a fine day, from the upper twigs of a heap of brushwood, into which it dives as soon as you appear. It is a familiar, fussy little bird, in habits and manner very like our own wren. It generally hatches out its large family very early, and they are probably the first young birds one sees in the spring.

Troglodytes aëdon (Vieill.) *House Wren.*—In appearance it reminds me more of the European bird, than any other of the Virginia wrens do. I have only noticed it in summer, when breeding, during which time it always remains about the homestead. Its song is good, and very sweet, and it is protected by law.

Troglodytes parvulus var. hyemalis (Vieill.) *Winter Wren.*—This little bird comes to Virginia for the cold months of the year, and I have not found it very common, and always singly Though not a shy bird, it is not as fond of human society as the two preceding species, and is seldom seen near the house, but prefers the wild forest, or the timber and brushwood growing by

some lonely river's bank. It seems to me to be generally darker in colour than the European wren, and rather stronger on the wing.

Cistothorus stellaris (Caban.) *Short-billed Marsh Wren.*—I have occasionally met with this bird on the margins of swampy ponds, but have not found it common.

Anthus ludovicianus (Licht.) *Titlark.*—It arrives in flocks early in March. The first I have noticed was on the 6th of that month. They make a stay of some weeks, longer or shorter according to the weather, and especially frequent newly ploughed lands. A few individuals remain long after the flocks have gone northward, but I doubt if any of them breed in the district. They appear again in autumn, in smaller flocks, but do not stay so long, though an occasional bird may be met with all through the winter. I have notes of having seen it on the 1st of December, and on the 15th of January.

Mniotilta varia (Vieill.) *Black-and-White Creeping-Warbler.*—Common. It arrives generally in the beginning of April. The earliest I have noticed was March the 30th. The males appear to arrive a considerable time before the females, and to be generally more numerous. In its way of running about the bark of trees, it much resembles the brown creeper, but it visits the smaller branches more than that bird does. Its song is a run of three notes, ascending by full tones, repeated four times, and ending with a single note one tone below the lowest of the others; but it is so rapid that it is difficult to distinguish it with certainty.

Parula americana (Bonap.) *Blue Yellow-backed Warbler.*—Not a common bird, and some years I have not seen it at all. I have only noticed it in spring and early summer. The earliest I have taken was on the 13th of April. It is generally found in pairs, among deciduous timber near some stream. Its song is a trill, ending with an abrupt jerk, like "whee-ŭ."

Dendrœca coronata (Baird.) *Yellow-rumped Warbler.*—This is one of the commonest warblers in the district, and spends great part of the year there. They come about the end of April, or the beginning of May, and remain until very late in the autumn. On one occasion I met a small flock on the 16th February during some very warm weather, in a sheltered valley in a

pine wood, and secured one; but with this exception I have never met with it after winter has thoroughly set in.

Dendrœca Blackburniæ (Baird.) *Blackburnian Warbler.* —I have never met this bird in the district but once. On September the 4th I took a young male of the year among some tall forest trees near my house.

Dendrœca striata (Baird.) *Black-polled Warbler.* It is not a common bird, and during several years I have not seen it at all. I have only noticed it in spring, when I have found it among deciduous timber. The earliest note I have of its arrival is the 13th of May.

Dendrœca cærulescens (Baird.) *Black-throated Blue Warbler.* —This handsome warbler is not very common, but may be obtained any day in the latter part of May at a place they have been observed to frequent, and every year one may be found now and then in the forest during spring and early summer; indeed I have never seen them except in deciduous timber. They are always in pairs, or a single male by himself. They arrive about the middle of May; the earliest I have noticed was on the 10th of that month.

Dendrœca pinus (Baird.) *Pine Warbler.*—This little bird outnumbers all the other Virginia warblers manyfold. The earliest date I have noted of its arrival is the 2nd of March, and it generally appears before the middle of the month. In about a week after its first arrival it is quite numerous, keeping itself exclusively to the pine woods, and by the middle of May those who intend to go further north have left, though a large number remain during the summer and build in the pine woods; indeed during spring and summer I have never seen one away from the pines. Early in October the return flight begins, and they come for some time in great numbers. Strange to say they then avoid the pine woods, and are found chiefly near the edges of the deciduous forests, and along the snake fences in the open land. One fence near my house has always been a favourite locality with the autumn flocks, which are composed largely of young birds, and every autumn I have seen them there in great numbers, though in spring I have never seen one on it. They are pugnacious little birds, and I have often seen them in autumn attack the tufted tits and chip-sparrows. The former always fled ignominiously, but the plucky

little sparrows like nothing better than a rough-and-tumble fight, yet, with their stout bills and their warlike dispositions, I could never see that they gained any advantage over the warblers, who in spite of their feeble appearance seemed quite their equals. Their song is rather sweet, but consists of only two notes very rapidly repeated.

DENDRŒCA DISCOLOR (Baird.) *Prairie Warbler.*—A summer visitor, and not common. The earliest note I have of its arrival is the 29th of May, but I have no doubt it comes much earlier, as I have found its eggs hard-set on the 1st of June. As its nesting has been but rarely observed I shall describe it. It had built in the fork of a dogwood bush about eight feet from the ground. The external diameter of the nest was 3·10 inches, internal diameter 1·70; depth, external, 3 inches; internal, 1·60. It was composed of dry grass and fine grass stems, mixed with soft vegetable down, and long shining vegetable fibres like tow, and lined with the finest of these materials, chiefly very fine stems and cotton. It contained four eggs which were white, specked with dark and light shades of brown, the latter having a lilac tinge. These specks are massed together near the larger end, forming a very distinct ring round the egg. Although called the Prairie warbler it confines itself almost entirely to trees and brushwood.

SEIURUS AURICAPILLUS (Swains.) *Golden-crowned Thrush.*—This little bird is not uncommon in spring and summer. I have taken it first on the 17th of May, and have found it in full song and apparently breeding on the 25th of that month. It sings with a monotonous, unmusical note.

SEIURUS LUDOVICIANUS (Bonap.) *Long-billed Water Thrush.*—I have first observed its arrival from the south on the 16th of April, after which, in spring and summer, one may commonly hear in the woods its song, resembling "tu-wee, tu-wee, tu-wee, te witte witte witte." It is fond of running over the mud by the river-side, catching insects, and jerking up its tail in a very wagtail-like way, but it is also commonly found in the woods far from water, generally, I think, in spring.

GEOTHLYPIS TRICHAS (Caban.) *Black-masked Ground-warbler.*—This very handsome little bird, sometimes called the Maryland Yellow-throat, is common in spring and summer near swampy

ponds, some seasons much more so than others. The earliest I have taken was on the 10th of April. Its song is very peculiar, though not musical, resembling "ēete-wet-ŭ," generally three times repeated. It always remains near the ground, among the thick low bushes. Its note of alarm is "cher-r," delivered in a very wren-like manner, as it peeps at the intruder from the thickest part of the cover.

ICTERIA VIRENS (Baird.) *Yellow-breasted Chat.*—They come every spring, and remain during the summer. The earliest arrival I have noted was on the 30th of April, and sometimes I have not seen them until nearly the middle of May. It is a handsome bird, and its song, though rather metallic, is not bad.

SETOPHAGA RUTICILLA (Swains.) *American Redstart.*—This is another very handsome little bird. It prefers trees to low bushes, and is generally seen at some height from the ground. It arrives early in May, the first comers being single males. The earliest I have noticed was on the 23rd of April. They pass again in September in little families, but some remain throughout the summer. Their song is rather metallic, and resembles "d'way-de-de-da-le," repeated perhaps two or three times.

PROGNE PURPUREA (Linn.) *Purple Martin.*—I have taken the first purple martin on the 2nd May. They remain all the summer, and are very common, especially frequenting the homestead, where a box, like a small pigeon cot, is often erected on a pole for them to nest in. They are encouraged to build near the farmyard, in order that they may protect the poultry, by mobbing any hawk which may come prowling about.

PETROCHELIDON LUNIFRONS (Baird.) *Cliff Swallow.*—I have only seen this bird once in Virginia. On 18th May, 1878, I saw a single pair, hawking about for some time in company with other swallows, of which large numbers were present at the time.

HIRUNDO HORREORUM (Barton.) *American Barn-swallow.*—This bird, which so forcibly reminds one of our own chimney swallow, arrives in the first part of May, the 2nd of that month being the earliest date on which I have noticed it. They remain but a short time and then go on to the north. A few may be seen returning in autumn, but they pass without stopping, and one does not see so much of them as in spring.

HIRUNDO BICOLOR (Vieill.) *White-bellied Swallow.*—It arrives in company with the last species, and their migrating movements seem very similar. They are about equally numerous, but *H. bicolor* seems perhaps to mix more freely with other species than does *H. horreorum.*

STELGIDOPTERYX SERRIPENNIS (Baird.) *Rough-winged Swallow.*—This is the most numerously represented species among the swallows. It arrives at least a fortnight earlier than the two preceding species, and in considerable numbers. The earliest that I have taken was on the 17th April, and though most of them appear to leave by the beginning of June, yet a few may be seen now and then throughout the summer.

COTYLE RIPARIA (Boie.) *Sand Martin.*—I have never taken this species, but I believe I have seen it not unfrequently, and once, 18th May, I have certainly done so.

VIREOSYLVIA OLIVACEA (Bonap.) *Red-eyed Vireo.*—In summer this is perhaps the commonest bird found in the woods. I have not noticed its arrival as soon as many of the other small spring migrants—not, indeed, until May is well advanced. They are indefatigable in hunting for larvæ, on which I believe they chiefly subsist, but on one occasion I saw one eating a large brownish beetle or cockroach, holding it on the bough with its foot, picking off first the legs and wings, and shifting its foot now and then to get a better hold. During the blazing heat of the midday sun, when the leaves hang down from the trees, when all life is still, and the woods seem asleep, the little red-eyed vireo may yet be seen hopping quietly about among the branches, the only living thing that has energy to move.

VIREO NOVEBORACENSIS (Bonap.) *White-eyed Vireo.*—Not nearly so common as the last, and is found among the thick bushes which border the streams and rivers instead of in the woods. The earliest note I have of its arrival is 20th of April. Its song is very marked and peculiar, though not musical, and resembles "kit-a-witch-ha-wai-e-o."

AMPELIS CEDRORUM (Sclat.) *Cedar Bird.*—This is a winter visitor, being most common in December. I doubt if any of them nest in the district, though I have taken immature birds as early as August the 7th. I have seen it stated that they are perfectly mute, but although they are remarkably silent birds,

they often utter a low call note resembling "isth," like the noise made by drawing the breath between the teeth.

Collurio ludovicianus (Baird.) *Logger-head Shrike.*—This bird is by no means common. I took a pair on March the 16th and 20th, and have occasionally seen a solitary individual in other years. The male of the pair I took contained a number of feathers of the song sparrow.

Pyranga rubra (Vieill.) *Scarlet Tanager.*—This is not a common bird, but a few may be seen every summer. The first I have noted was on the 29th of April. They remain throughout the summer, and in some years are more plentiful than in others.

Pyranga æstiva (Vieill.) *Summer Red-bird.*—Common throughout spring, summer, and autumn, arriving in the end of April. For several years I have noticed it first on the 24th, and once on the 21st of that month. At one time I thought the male arrived before the female, but later observations convinced me that this was not the case, but the bright scarlet plumage makes him a much more conspicuous object than his mate, whose dull dress often causes her to be overlooked. His song is rather good, and the bright colour of the male makes him a handsome object among the green leaves. They are always found in the woods.

Carpodacus purpureus (Gray.) *Purple Finch.*—Not common. Some years I have not noticed it at all. I have generally found it in spring, or the end of winter, frequenting either the edges of deciduous forests, or the thick pine woods.

Chrysomitris tristis (Bonap.) *American Goldfinch.*—All through the year they are not uncommon, but they arrive in large flocks in April, and during that month are very plentiful. They are locally known as the "lettuce-bird," on account of their partiality for the seeds of that plant; and a large flock, if permitted, will soon cause great havoc in a garden among the beds of lettuce seeds that have been lately sown. It is an extremely handsome little bird in spring and summer, and a flock of them dressed in full nuptial plumage is very striking.

Passerculus savanna (Bonap.) *Savanna Sparrow.*—This is a winter visitor. The earliest arrival I have observed was on the 24th of October. They remain until quite late in the spring, but I do not think any of them stay through the hot season. They are com-

mon in open fields, and creep away quickly through the grass, or run along the path before one's horse like a mouse, often tumbling over a stone or clod in their haste, but exhibiting the greatest reluctance to take wing; but if persistently followed up, they will rise and fly a few hundred yards before alighting.

COTURNICULUS HENSLOWI (Bonap.) *Henslow's Sparrow.*—This rare, or perhaps I should say very local little bird, I have met but on one occasion. On the 8th of April, when collecting early in the morning, I saw a sparrow dive into some low scrub, uttering a note that was strange to me. On being approached he darted from bush to bush, just as the European wren does, and soon hid himself away securely. However I sat down, and waited patiently, and in about ten minutes he came out and commenced searching about through the grass at the roots of the bushes and was secured.

COTURNICULUS PASSERINUS (Bonap.) *Yellow-winged Sparrow.* This little bird is not uncommon in summer in open fields, where there is coarse grass or stubble. There it may often be found singing its remarkably feeble song, from the top of some low bush or pile of stones. The earliest note I have of its arrival is the 30th of April.

ZONOTRICHIA ALBICOLLIS (Bonap.) *White-throated Sparrow.*—It arrives in October, the earliest I have noted being on the 12th of the month. It remains throughout the winter and leaves again in April. I do not think I have ever seen them in May, except once when I shot one on the 10th of that month. They are hardly ever seen in the fields, like the preceding species, but confine themselves chiefly to the vicinity of the homestead. There however they are in winter, one of the commonest of the small birds, frequenting bushes, or piles of logs and brushwood, into which they dive when alarmed. As spring approaches they sing generally on a wet morning or when rain is threatening, if it be not too cold. Often just at dawn before getting up I have known that it was a misty morning by hearing the song of this little bird; it is a very poor or rather doleful performance, consisting of but five notes—one a high one, then three tones below, another repeated slowly four times.

JUNCO HYEMALIS (Sclat.) *Snow Bird.*—They spend the winter in Virginia, coming soon after the first sharp frosts. The earliest

I have noted was the 23rd of October. They are by far the most numerous of the small birds in winter, hundreds of them being often seen together. They generally begin to leave again in March, but an occasional straggler will sometimes remain until late in April. Two or three cold nights will sometimes bring back a few, when none have been seen for a week or more. I once noticed three on the 20th of April, and in another year, a solitary individual on the 23rd of that month. They must not be confounded with the Snow-bunting, which is known in Canada as the Snow-bird.

SPIZELLA MONTICOLA (Baird.) *American Tree-Sparrow.*—A rather uncommon winter visitor. I have taken it first on the 7th of December. Like all the species of the genus *Spizella* it shows, when in the district, no partiality for the farm-yard, but prefers trees and bushes in the open fields, or along the margins of woods.

SPIZELLA PUSILLA (Bonap.) *Field Sparrow.*—It remains all the year, but seems most numerous in winter, when it congregates in little flocks of from ten to twenty. After a few very cold days their numbers always seem to increase, as if they had been re-inforced by a partial migration from further north. They are chiefly met with on the bushes in the open fields, or along the road side.

SPIZELLA SOCIALIS (Bonap.) *Chipping Sparrow.*—This little sparrow arrives in flocks late in March, and in a few days after its first appearance it becomes very plentiful. The earliest note I have of its arrival is the 23rd of March. The males fight incessantly in the most determined manner, screaming and twittering most viciously, three or four battles being often carried on together close to each other, and they are so engrossed in their occupation, that one might almost take them in one's hand; they fly up and down, and tumble over each other, and I once found one so exhausted that he was unable to fly. On catching him, I saw that he had all the feathers pulled off his forehead, and all his remaining tail feathers broken.

It is a great fly catcher, and I have seen it capture, and pick to pieces, even large beetles. Its song consists of only one tone —the same note repeated slowly three times, followed by a long rapid trill.

They leave during November, and by the end of the month not one remains.

MELOSPIZA MELODIA (Baird.) *Song Sparrow.*—They arrive in December, the earliest I have noted is on the 7th, and remain during the winter, leaving in spring as soon as the weather begins to get warm. Early in spring they sing incessantly, and their song is very sweet and pleasing. During their stay they frequent the vicinity of the homestead, in company with the white-throated sparrows.

PASSERELLA ILIACA (Swains.) *Fox-coloured Sparrow.*—This is not an uncommon bird during winter, being generally seen singly. It comes rather late, the earliest arrival I have noted being November the 10th; and it leaves early. I have never seen one after the 15th of March. Early in that month they sometimes congregate in little parties of five or six, and then disappear; but most of them have left by the end of February.

GUIRACA CÆRULEA (Swains.) *Blue Grosbeak.*—Not uncommon in the end of April, and in May. The earliest I have taken was on the 26th of April. They are generally found singly, or in pairs. Whether a few remain throughout the summer or not, I am not certain.

CYANOSPIZA CYANEA (Baird.) *Indigo Bird.*—For several years I have first noticed its arrival on April the 30th; and they seem to be among the first birds to leave, departing soon after the young are strong on the wing. They are very common, and in spring they sing incessantly. Their song resembles "ēet-et-te-ĕ, dēet-eet-te-ĕ, wet-et-te-ĕ, tue tue tue tue," with a loud scolding alarm note. They very often, however, sing only part of their song. I have frequently seen them singing vigorously on the wing, as they fluttered and floated from one tree to another, a distance of sometimes as much as two hundred yards. The female seems much shyer than her mate, and partly owing to this, and partly to her more sober dress, is comparatively seldom seen.

CARDINALIS VIRGINIANUS (Bonap.) *Cardinal Grosbeak.*—This bird, often known in England as the Virginia Nightingale, is very common all the year round, and I believe does not migrate, even in the most partial manner. They were especially numerous

round my house, where they were not molested, and though they never assemble in flocks, I have counted as many as thirteen on one small tree near my corn house, nine of which were males. They are very bright, handsome birds, and their song is sweet and powerful, but rather monotonous. I have seen the female in spring, singing in the woods just as well as the male. They build their nest in some bush or low tree, generally only a few feet from the ground. It is generally composed chiefly of the stalks of the Michaelmas-Daisy (*Aster Americanus*), and I do not think I have ever seen a nest that had not some of this material in it. It is locally known as the Red-bird, and is protected by law.

PIPILO ERYTHROPHTHALMUS (Vieill.) *Red-eyed Towhee.*—It is commonly known as the Ground-robin. In March they are often quite numerous; the earliest that I have taken was on the 22nd of February. Some remain all the summer, and assemble in flocks in the autumn, and these being augmented probably by those migrating from the north, it becomes a very common bird in the beginning of October. After the middle of that month most of them have left, and I doubt if any remain during the coldest part of the year. It frequents thick bushes and underwood, and always keeps near the ground.

EREMOPHILA ALPESTRIS (Boie.) *Shore Lark.*—It comes to this district in flocks during winter. Some years I have not seen one; in others I have noticed that they appeared whenever the weather was unusually severe, and then only, leaving whenever it became the least warmer. They prefer open pasture fields, or stubble that has been grazed bare, and seem during their stay to be much attached to a locality which they consider suits them. I have always found them rather wild and hard to approach within shot; and I have noticed a flock that I had disturbed, fly over another flock—who were feeding in a valley where they had not observed me—and swoop down at them several times, until they induced them to rise and join them, when they all flew off out of danger.

DOLICHONYX ORYZIVORUS (Swains.) *Bob-o-link or Rice-bird.*—It arrives in flocks about the middle of May. I have not seen it before the 8th of that month. They stay but a very short

time—only a few days—and then are not seen until autumn, when they pass as before.

Molothrus pecoris (Swains.) *Cowbird.*—They arrive in large flocks in the latter part of February; I have taken them first on the 25th of that month. They remain for some time, frequenting in great numbers ground that has been newly sown, or where the grass has been burnt off. Whenever there is a return of cold hard weather they disappear, but the first few fine days bring them back again. With them are mixed flocks of the red-winged blackbird, and smaller flocks of the purple-grackle, which act in the same manner. When the weather has settled down to be warm and fine, the cowbirds leave for the north.

Agelaius phœniceus (Vieill.) *Red-winged Blackbird.*—These arrive in flocks about the same time as the last; the earliest I have seen was on the 21st of February. They however remain throughout the summer, and during the nesting season frequent swampy places near rivers or ponds. The female often suspends her nest from the reeds about a foot or two above the water, while the male spends the whole day among the willows close by, singing and chasing the female whenever she appears. He comes up to her with a flood of song, his tail spread to the utmost, his wings extended and fluttering, displaying to the greatest advantage the bright patch of scarlet. As he sails slowly up, he looks twice his real size, and is quite a beautiful bird. Then when she bolts, as she generally does, he chases her rapidly round and round, with much singing and squalling.

Sturnella magna (Swains.) *Meadow Lark.*—A permanent resident, and very common. It frequents pastures and open lands, and does not seem to migrate in any way. In winter they assemble in flocks, somewhat as the European starling does, but more scattered and irregular, and not in such numbers. In changing their quarters from one field to another, a few will get up and fly perhaps a quarter of a mile, followed at a distance of a few hundred yards by one or two more, and so on until the whole of them have assembled again, but I have never seen them fly in a compact mass, as starlings do. They build their nest in some hollow in the ground, and it is roofed over with grass stems, like that of the ortyx, but flatter.

Icterus spurius (Bonap.) *Orchard Oriole.*—It arrives in May, the 8th of that month being the earliest that I have taken it. It remains throughout the summer, but is not very common.

Scolecophagus ferrugineus (Swains.) *Rusty Grackle.*—They arrive in flocks about the same time as the cowbirds, and associate with them. I have never taken them before the 19th of March. They leave when the weather gets warm, and return in November in flocks, passing south. The earliest date at which I have found them returning was on the 9th of November.

Quiscalus purpureus (Bartram.) *Purple Grackle.*—Arrive at the same time as the cowbirds (end of February), but do not associate with them so much as the last species, and are in smaller flocks. They remain until autumn. Numbers of them nested in some ivy-covered trees, near a house of one of my friends, and being very pugnacious they would permit no other bird to remain in the compound, or yard, as it is there called. They were very noisy, and assembled every evening making the most horrible, metallic, discordant sounds, intended, I believe, for song. I have always found them thus assembled before sunset on some high treetop, from the time the flocks first arrive, and their chatter can be heard at a long distance.

Corvus americanus (Aud.) *Crow.*—A permanent resident, and in its habits much like the rook. The flocks, however, are but from three or four to twenty in number, and in its nesting it is solitary like the carrion crow, which it closely resembles. It has not, however, the pointed feathers on the neck like that bird, nor the bare skin at the base of the bill like the rook. Its voice is a much shorter "caw" than that of the rook, and more jerky, and reminds a new comer of a dog barking, though the resemblance seems to wear off when one gets accustomed to it.

Cyanura cristata (Swains.) *Blue Jay.*—I have not found this bird very common, it is most numerous, I think, in winter and spring. It is a shy bird, and generally keeps to the woods, and as much out of sight as possible.

Tyrannus carolinensis (Baird.) *King Bird.*—The Bee-martin, as this bird is called in Virginia, comes in the end of April. I have noticed its arrival in different years, from the 23rd to the 28th of that month. It appears to have paired before its arrival, as I have always noticed two of them together from the

first. It is a common bird throughout the summer and early autumn, and then leaves for winter quarters.

MYIARCHUS CRINITUS (Caban.) *Great Crested Flycatcher.*—Not uncommon in the woods in summer. It arrives, I think, about the beginning of May, but the earliest that I have taken was on the 23rd. I have found it most common in warm summers.

SAYORNIS FUSCUS (Baird.) *Pewee Flycatcher.*—It arrives in March, and leaves after the first frosts. But I have several times, to my no small surprise, seen it in the middle of winter, on the 3rd and 4th of January. It is a common bird in summer, and may often be seen perched on a post, or the top of a tobacco-barn.

CONTOPUS VIRENS (Caban.) *Wood Pewee.*—It arrives in the middle of March. The earliest note I have of it is on the 10th. I have never seen it in winter though it will stay for some time after frost commences, and remains longer than the last species. It is common in the woods all through the warm weather.

CERYLE ALCYON (Boie.) *Belted Kingfisher.*—I have never seen this bird in winter. They appear in spring, and disappear when it gets cold, but I have unfortunately no notes of their arrival or departure. I have found it nesting in a hole in a steep bank, the side of a cutting through which the public road passed. Yet so cautious was the bird in approaching its nest, that I had great difficulty in finding it, and it eventually brought away its young brood in safety to the river, which was about a hundred yards off.

CHORDEILES POPETUE (Baird.) *Virginia Goatsucker.*—This bird is locally known as the "bull-bat." The earliest date at which I have noted its arrival was the 23rd of April. They soon become common, and remain until the middle of September. At that time I have seen flocks of them sailing round high up in the air, after which they disappear entirely. They fly a good deal by day, but are then high up, only coming down and skimming near the ground in the early dawn or late in the evening.

ANTROSTOMUS VOCIFERUS (Bonap.) *Whip-poor-Will.*—I have noted first arrivals of this bird in different years from the 7th to the 17th of April. During May their cry is incessantly ringing through the woods in the morning and evening, especially if it happen to be a little cooler than usual. They are very tame,

and if one remains quiet they will often come and cry within a few feet of one, generally selecting a log or rail, or some bare spot of ground. I have noticed that a white patch, where some mortar had formerly been made up, was always especially attractive to them, and two or three of these patches were always frequented nightly by the males calling to their mates. On these white patches they were most conspicuous in their dark dress, and I believe that was their reason for frequenting them. They remain all the summer, and leave about the middle of September. Some years they are much more abundant than others.

CHÆTURA PELAGICA (Baird.) *Chimney Swift.*—My earliest note of its arrival is the 19th of April. It is common throughout summer and remains until autumn.

TROCHILUS COLUBRIS (Linn.) *Ruby-throated Humming-Bird.*—It arrives in the beginning of May. I have taken it as soon as the 18th of April, but that is earlier than usual. For the first two weeks in May they are quite abundant; afterwards when many have passed north, they are not so numerous, though common until autumn. After the 25th of August they are very numerous for a little time; the young broods, I suppose, perhaps augmented by arrivals from the north. I have never noticed one after the 6th September, although in Lower Canada I have seen them up to the 7th. I have taken their nests, with the eggs hard set, on the 27th May and 1st of July. I have never seen the female act as Mr. Webber describes;* mine when returning to their nests always flew up boldly, and settled on or near it, just as any other bird might do.

I find that on account of the turned-in lip, with which these beautiful little nests are furnished, they will bear being inclined at an angle of 135° from the perpendicular, or nearly upside down, before they will allow the eggs to fall out.

They are hot-tempered little birds, and I have often seen the males quarrelling with each other, darting up and down perpendicularly, to a height of twenty or thirty feet so rapidly that the eye can hardly follow them, uttering all the time a sharp, squeaky note of anger. I have sometimes myself been attacked in the same way by one of these little birds whose indignation I had in

* "Wild Scenes and Song Birds."

some manner aroused, and they dart up and down within three or four feet of one's face squeaking most viciously, though there was no nest in the immediate vicinity that I could find, and I have never seen any such display when their nest has been approached.

COCCYZUS AMERICANUS (Bonap.) *Yellow-billed Cuccoo.*—This bird is locally known as the "rain-crow," from its being supposed to call before rain, or when rain is much wanted. I have generally noticed it most noisy in very sultry weather, and it will call persistently in the middle of the hottest summer's day, when all other birds are silent. I once (June 30th) heard it calling at 10.30 P.M., no moon, after heavy rain. It comes early in May, and remains throughout the summer. The earliest arrival I have noted is the 1st of May.

PICUS VILLOSUS (Linn.) *Hairy Woodpecker.*—Not very common. I think it is a resident all the year, but it is most usually seen in winter, spring, and early summer.

PICUS PUBESCENS (Linn.) *Downy Woodpecker.*—This is the commonest of the woodpeckers in the district, and the smallest. It remains throughout the year, but migrates partially I believe.

SPHYRAPICUS VARIUS (Baird.) *Yellow-bellied Woodpecker.*—This is a common bird in the woods in winter, but leaves generally before the end of March. The earliest note I have of its return is the 15th of October. I have noticed this woodpecker sitting on a tree soon after its arrival, constantly launching itself into the air, and catching insects on the wing like a flycatcher. I have also repeatedly found the crops of those I have shot containing numerous cedar berries. All woodpeckers seem to prefer deciduous timber, but this one may be found on the pine trees more frequently than the others. I think the females remain a little longer in the spring, and return a little earlier in the autumn than the males. This and the last are locally known as "sap-suckers."

HYLOTOMUS PILEATUS (Baird.) *Pileated Woodpecker.*—This large woodpecker, locally known as the "log cock," is a permanent resident. Its size, and its brilliant crest, make it a very striking object in the woods; and the beautiful pale primrose of the underside of the wing is very conspicuous when it is flying.

I have noticed, that in all the specimens I have taken, the iris of the male was fawn colour, and that of the female the colour of the inside of a pomegranate.

Centurus carolinus (Bonap.) *Red-bellied Woodpecker.*—This bird remains all the year, and is not uncommon at any time. It is found chiefly in the deciduous forests, where there are large trees, and is seldom met with among the large bushes or smaller trees by the road-side, as *P. villosus*, and *P. pubescens* often are.

Melanerpes erythrocephalus (Swains.) *Red-headed Woodpecker.*—This is the handsomest of the Virginia woodpeckers, and not very common. It is a summer bird, the earliest arrival I have noted is the 10th of May. On the 19th of September, 1877, my house was visited by quite an incursion of them; they were principally young birds, and remained for two or three days; and were, during that time, more numerous than all the other birds put together. I suppose they were the northern contingent going south. This woodpecker may often be found on single trees, away from the forest, or any other timber; indeed, it almost seems to prefer trees that are thus dotted about the open country, to masses of woods.

Colaptes auratus (Swains.) *Golden-winged Woodpecker.*—It is locally known as the "yucka." It is found all through the year, but I believe migrates partially. Their courtship in spring is very amusing. They may be seen, I think, more frequently on the ground than other woodpeckers, and I have often seen them perched crosswise on a bough, as birds generally do, instead of lengthwise, or on the stem in the more approved woodpecker fashion.

Syrnium nebulosum (Aud.) *Barred Owl.*—This is a rather common species, about equally so with *B. virginianus.* They much frequent the woods round my house, and in spring make the most unearthly noises at night, laughing, screaming, and caterwauling at each other, like demons or madmen. Their usual note is in a higher tone than that of the great owl, and resembles "huh, huh, hoo, hooo, hooo." They often hoot in the day-time, and even come out about 4 p.m., if rain is threatening. I have often sat near a tree on which the young were perched, and watched the proceedings of the parents. The male always seemed more anxious and bolder than the female. I have never found

their stomachs to contain anything, except crayfish, and a salamander that lives under old logs.

Scops asio (Bonap.) *Mottled Owl.*—This little owl is very common, especially in July, when the young begin to fly. In the summer evenings may be constantly heard their long, plaintive, tremulous cry: "ŭ, ŭ, ŭ, ŭ, ŭ," except before rain, when they are generally silent. The red and gray form seem to occur indiscriminately in any age or sex. The grays are not bad eating, tasting something like woodcock; but the red ones that I have tried, were not nice.

Bubo virginianus (Bonap.) *Great Horned Owl.*—Not an uncommon bird, and its deep "hoooo-hoo-hoo," may often be heard in the moonlight, or early dawn, especially in spring. In the distance their voice seems to have a tremulous tone, and the first note is the longest. A friend of mine shot one in the act of carrying off a skunk, and the bird smelt so dreadfully of its evil odoured captive, that he could not preserve the skin.

Falco sparverius (Linn.) *American Sparrow Hawk.*—This pretty little kestrel, is the commonest hawk in the district, and remains throughout the year. It is very fond of roosting in tobacco barns in winter. I have seen it mobbing the big red-tailed hawks most gallantly. I have watched it engaged in catching locusts: sitting on a rail fence and pouncing on them in the grass, and I have found its crop full of them; but it also eats small birds.

Pandion haliaetus (Linn.) *Osprey.*—This is rather an uncommon bird in the district, though I believe more abundant near the large rivers. I have generally seen it in April.

Circus cyaneus var. hudsonius (Ridgw.) *Marsh Hawk.*—This form of the hen harrier is locally known as the "Blue-winged Hawk," from the colour of the adult male. Although said to be a permanent resident much further south than Virginia, this is certainly not the case there, as far as my observations have gone. It is most markedly a winter visitor, and is quite common during that period; one may often see six or eight of them during the day, sweeping over the open lands, and carefully beating up any fertile valleys, where masses of tall weed-stalks, the remains of the summer's growth, afford good cover for their prey. My earliest record of its arrival is the 27th of October, and it leaves

about the middle of April. On one occasion only have I met with it at any other time. On the 1st of August I observed a hawk, which I thought was an immature bird of this species, but I am by no means sure of its identity, as it was very wild, and would not permit an approach within several hundred yards, even on horseback.

Nisus fuscus (Gm.) *Sharp-shinned Hawk.*—Not a very common bird, but may occur, I think, at any time of the year.

Nisus cooperi (Bonap.) *Cooper's Hawk.*—Rather common in summer, but I have never seen it in winter. It seems to arrive in spring, and to leave in the autumn. I once watched two of these hawks, that spent the whole morning, from a little after sunrise, trying to catch a pileated woodpecker, who, though screaming loudly at each swoop, did not seem to care much about them, but went on hunting for insects all the time, merely slipping round the tree when one of them struck at him. Sometimes he would remain still for a few minutes, as if watching them, and if they were at some distance, he would flap off to another tree; but the moment they saw him on the wing, they would pursue him again. About 9 A.M., I fired at and wounded one of them, and the persecution ceased for the time. The woodpecker went on hammering at the trees near my house, and in about half an hour, I again saw him attacked by a single hawk of this species, which I suppose was one of the pair. The persistent determination of these birds, to compass the destruction of this particular woodpecker, struck me as odd; for they could easily have obtained their breakfast by pouncing on one of my hens, which they not unfrequently did; indeed they are considered the worst of all hawks for destroying poultry.

They are seldom found away from timber, and generally frequent the borders of or the clear patches in woods, or roads running through them.

Buteo borealis (Gm.) *Red-tailed Hawk.*—This fine buzzard is common, and remains throughout the year. It preys chiefly on squirrels and hares. In spring, before the leaves are on the trees, it may often be seen sitting on some tree by the roadside, and will then allow you to ride close past it; but it generally recognises a gun, even on horseback. When a field covered with coarse wild grass has been set on fire, I have seen several of

these buzzards wheeling about in the smoke, doubtless hopeing to snap up some unfortunate hare, driven from its form by the flames. Their flight is often extremely graceful, as they wheel round in circles, on wings spread to the utmost, a pair crossing and recrossing each other, one being a good deal higher than the other.

HALIAETUS LEUCOCEPHALUS (Linn.) *Bald Eagle.*—Very rare in the district, but more abundant on the lower part of the James river. One was shot by a neighbour of mine, while feeding on a dead sheep.

CATHARTES AURA (Linn.) *Turkey Buzzard*—A very common bird all the year, but comes more under our notice in winter, when in the cold weather, beef, pork, and mutton, are being cut up and prepared. Then they may be seen sitting in rows, on the ridges of the roofs of the outhouses, or grouped on some tree close by. They will sit on a fence, by the roadside and let you ride past quite close. No one molests them; indeed I believe they are protected by law.

Regarding their nesting in Texas, Mr. Dresser says (*Ibis*, 1865, p. 322):—

"The nests I have seen were large, bulky, composed of sticks, and generally placed, at some height, on a cypress or an oak, near the river bank." But he also says—"I have never succeeded in taking any of its eggs, but was shown many nests," &c. This is so opposed to anything I have seen myself, and to any information I have obtained from others who knew the bird well, that I cannot help thinking Mr. Dresser's informants must have mistaken the nests of some other bird (probably the Osprey, or perhaps a Buzzard), for those of this vulture. All the nests I have found—or that I have heard of in my district—have been in a hollow log, or the hollow stump of an old tree; and the only approach to nest-making that I have observed, is the slight hollow in the decayed wood, where the eggs lie, and even this is generally dispensed with. The eggs I have always found two in number, in one of which the markings have been invariably larger, bolder, and more blotchy than in the other.

ECTOPISTES MIGRATORIUS (Swains.) *Passenger Pigeon.*—The wild pigeons pass in flocks going north about the middle of March, and often remain a week or two in the district. Probably each

individual does not stay so long, but one band replaces another as they move on. They pass again in larger flocks on their way south, about the middle of October; but now and then you may see one at any time during the summer. I have been assured by the negroes that they occasionally nest in the district, not in large colonies, but a single pair here and there. I have seen the young quite small, though able to fly, following their parents in August; and a friend of mine has shot them still covered with nesting down. So probably a pair does sometimes remain.

ZENAIDURA CAROLINENSIS (Bonap.) *Carolina Dove.*—They remain the whole year. In spring they are often extremely tame where not molested, and all day long their cooing is heard in the woods, but in autumn, when they pack in flocks, they are often difficult to approach. I think they are perhaps not so numerous during the colder months of winter as at other times of the year, and perhaps a partial migration may take place to some extent.

MELEAGRIS GALLOPAVO (Linn.) *Wild Turkey.*—This fine bird is still not uncommon in the district, although becoming scarce in most parts of Virginia, where it is not altogether extinct. The hens generally weigh from eight to ten pounds, and the goblers when full grown, seventeen pounds. The largest I ever shot weighed twenty pounds, and the largest I have known was twenty-three. The males gobble vigorously in March and part of April, and are then often shot by calling them up, by imitating the note of the hen upon an instrument (know as a "yelper"), made from the radius of the hen—that bone in the gobler not giving so correct a note—as a mouth piece, and a trumpet-shaped piece, generally made of wood. This, however, is now illegal, as it can only be practised in the close season.

Turkeys are generally now hunted with dogs, trained to rush into the flock as soon as discovered, and scatter them in all directions, when they should bark to let the sportsman know that the game has been found. After a while the turkeys will call each other, and assemble together, seeking as a rendezvous, the spot from which they were scattered. Near this place the sportsman builds a blind, of logs or bushes, and awaits the turkeys return, calling now and then with his "yelper." The time he may have to wait varies with the extent to which the turkeys have been previously hunted, and with the hour of the day, as when evening is

approaching, the birds will not remain separated so long as if scattered early in the day.

I once heard a male continue gobbling vigorously long after dark; and I have also heard them gobble in the month of December, but it is most unusual for wild turkeys to do so.

BONASA UMBELLUS (Stephens.) *Ruffed Grouse.*—Although plentiful in the mountains, this is not a common bird in the district of which I write, though a few pair hatch their young every year in the thick pine woods, and remain all the year, and they sometimes drum close to my house in spring.

It is here locally known as the pheasant, though in the north it is called the partridge.

ORTYX VIRGINIANUS (Bonap.) *Partridge.*—The quail of the northern and western states. It is very abundant, and not a migrant in Virginia. I have heard the cock commence his amorous call of "bob-white" on April the 22nd, May the 7th, and May the 9th, in different years. In two instances I have strongly suspected this bird of removing its eggs, when I have unconsciously almost trodden on them. In one case the whole nest was taken away, and this was situated in the heart of a large pinewood of many hundred acres, on the edge of a little open spot, where no person would be likely to find it. I think the bird, which had just begun to lay, removed its eggs, and pulled the old nest to pieces to get materials for a new one.

In two other instances I have suspected birds of removing their eggs, and in one of these cases the circumstantial evidence almost amounted to proof.

ÆGIALITIS VOCIFERUS (Linn.) *Kildeer.*—This plover is a constant resident, and may be seen at any time of the year on open ground, preferring short grass pastures. It is most common in spring and summer, and I think a partial migration takes place in winter, and that some of them leave for more southern quarters.

PHILOHELA MINOR (Gm.) *Woodcock.*—I think they leave during the colder months of winter, but are common at other times, especially in spring and early summer. Their wings make a strange whistling noise. During the season of courtship they have a habit, late in the evening, of springing from the ground and flying vertically upwards to a considerable height, the tone

of their whistling wings rising and falling like a song. The males also bleat much like the English snipe, but this is always done on the ground.* I have shot them in the act to satisfy myself on the subject. I believe it is a call to the female. They chose some clear spot in the open land, where the heavy rains have washed the subsoil bare—locally called "galls,"—and to this they repair a little after sunset, just as it is getting dark. The same spot will be tenanted by them every night, bleating for their mates. I have seen woodcocks fly to the bleating birds, which I presume were females, though I have never shot one to determine the sex.

Gallinago wilsoni (Temm.) *Wilson's Snipe.*—This bird was very uncommon in my vicinity. I have only taken it twice, on both occasions in spring; once three birds out of four seen; the second a single bird on April 25th.

Rhyacophilus solitarius (Wils.) *Solitary Sandpiper.*—One occasionally sees it by the river side, especially where floods have backed the water out over the adjoining land. It is, however, not very common. I have taken it in May several times, and also once in autumn. I believe it remains all through the summer.

Ardea herodias (Linn.) *Great Blue Heron.*—Not very common, but may be seen occasionally throughout spring, summer, and autumn, fishing by the river side. The earliest date I have of its arrival is the 14th of April.

Butorides virescens (Linn.) *Green Heron.*—It arrives about the end of May, and is a common bird until autumn by the side of rivers and streams. I have often watched them creeping stealthily along the edge of the water by the river side, and pouncing like lightning on a little fish, which glitters for a moment in their bill. They also eat frogs, but I have generally seen them catch fish.

Botaurus lentiginosus (Mont.) *American Bittern.*—Not common. I have only seen it in spring.

Bernicla canadensis (Linn.) *Canada Goose.*—They arrive in October. The earliest record I have is the 22nd of that month. In December they are often in very large flocks on the lowgrounds bordering the rivers, whence the Indian corn has lately been removed. They generally assemble for the night on some

* On perfectly calm evenings when there was no wind to act on their feathers.

safe piece of water where they will not be disturbed, and during the day visit the neighbouring fields. I have observed they are rather late in leaving their retreat in the morning, seldom appearing until the sun is rising. They leave for the north in spring.

ANAS BOSCHAS (Linn.) *Mallard.*—This widely distributed bird is a winter visitor only, in the district, and leaves very early in spring, but during its stay is not uncommon.

AIX SPONSA (Linn.) *Summer Duck.*—They generally appear about the beginning of March. In the early part of that month they are common in pairs in the woods round my house, and may then often be seen perched on the trees. They are probably looking for a suitable nesting place. The earliest arrival I have noted is the 27th of February. They are common all the summer, and remain until late in autumn.

X.—DESCRIPTION OF THE INSTRUMENTS AND PROCESSES EMPLOYED IN PHOTOGRAPHING ULTRA-VIOLET SPECTRA, BY W. N. HARTLEY, F.R.S.E., &c., PROFESSOR OF CHEMISTRY, ROYAL COLLEGE OF SCIENCE, DUBLIN. PLATES 12, 13, 14, and 15.

[Read, April 11th, 1881.]

INTRODUCTION.

THE first successful photographs of spectra were executed by M. Edouard Becquerel (Bibliothéque Universelle de Genève, t. xl. 1842). Dr. J. W. Draper first photographed the sun's spectrum with a ruled diffraction grating in 1843 (Philosophical Magazine, June, 1845, and March, 1857). The work thus commenced has been continued in late years by his son, Dr. Henry Draper, of New York. In the year 1852 it was discovered by Professor Stokes that quartz absorbs the ultra-violet rays less than glass, and in 1853, when experimenting previous to the delivery of a lecture at the Royal Institution, he found the length of the spectrum of electric light yielded by the powerful discharge of a Leyden jar and analysed by quartz apparatus, extended no less than six or eight times the length of the visible spectrum. The obscure rays were rendered visible by receiving them on a fluorescent screen.—("On the Change of Refrangibility of Light," Phil. Trans., 1852, and "On the Long Spectrum of Electric Light," Phil. Trans., 1863). Professor Stokes studied the ultra-violet spectra of metals and executed drawings of the lines exhibited by aluminium, zinc and cadmium. He discovered the fact that certain solutions show light and dark bands in the spectra of rays transmitted by them, the solutions being colourless the bands are invisible unless they fall upon a fluorescent screen. The late Dr. W. A. Miller, of King's College, London, in 1863, simultaneously with Professor Stokes, described his method of examining the photographic transparency of various saline solutions and organic substances, and of depicting metallic spectra. A sensitised photographic plate was used for the reception of the rays of the spectrum, so that they were made to register their own position and intensity by means of chemical action. The photographed spectra

of many metallic elements were reproduced by mezzo-tint engraving and can be seen in the Philosophical Transactions, Part I., 1863, and also in the Journal of the Chemical Society, 1864. Having compared the engravings with the original negatives and with prints taken therefrom I can testify to their being faithful representations, but the character of the metallic lines is wanting in delicacy of detail and sharpness, such as we are accustomed to see in the visible spectrum. The reason of this will be explained further on. The photographic process was carried out with films of plain iodized collodion and a nitrate of silver bath, occasionally a bromo-iodized collodion was used, the developer being pyrogallic acid.

M. Mascart has examined the ultra-violet portion of the solar spectrum by means of photography, and has given us a drawing of a normal spectrum extending beyond H (Annales de l'École Normale, 1864). By the use of gratings engraved on glass by M. Nobert, and prisms of Iceland spar, he has made measurements of the wave-lengths of the ultra-violet solar rays as well as of the lines of cadmium, the spectrum of this metal being remarkable for the range beyond H, to which its rays extend.

There is a regular diminution in wave-length from the solar line H, $\lambda=396$ to 221·7 the extreme line of cadmium. It is remarkable that the shortest wave-length measured 221·7, together with the longest visible undulation, A, $\lambda=760$ constitutes with the intermediate vibrations a scale extending nearly two octaves. (Annales de l'École Normale, 1867.)

In the accompanying table the wave-length of the ultra-violet lines of cadmium as measured by M. Mascart are given. Frequent reference will be made to these measurements.

Wave-length of lines in that part of the spectrum of cadmium more refrangible than the solar line H.

Numbers of reference to Cadmium lines.	Wave-length.	Numbers of reference to Cadmium lines.	Wave-length.
8	398·56	15	—
9	360·75	16	—
10	346·45	17	374·34
11	340·30	18	257·42
12	328·75	23	231 83
13	—	24	226·56
14	—	25	221·76

Dr. Henry Draper was the first who obtained completely successful photographs of the sun's spectrum. He succeeded on one occasion in photographing on one plate the rays extending from near *h* (wave-length 516·7) to T (wave-length 303·2). The spectrum was produced by means of a very perfect ruled glass grating made by Mr. M. L. Rutherford of New York. The jaws of the spectroscope slit were made of steel and were moveable by a micrometer screw, the width of the slit used was $\frac{1}{110}$th of an inch.

In order to obtain a spectrum of uniform character for rays of all refrangibilities, parts of the sensitised plate were protected by a series of diaphragms, during exposure for faint groups of rays; by the removal of these at intervals the strong rays were photographed with a distinctness which could not otherwise have been obtained. The sensitive plates used were prepared with bromo-iodized collodion and sensitised with a nitrate of silver bath.

Dr. Draper's fine photographs show how impossible it is to depict the relative intensities of lines in the spectrum by any other means than photography, and how groups of lines even may fail to be resolved. In fact as he states "*The exact composition of even a part of the spectrum of a metal will not be known until we have obtained photographs of it on a large scale.*"

Dr. Draper comments on the unsatisfactory nature of Miller's photographs in the following words:—

"I have also tried to utilize the photographic spectra of the late W. A. Miller, published in the Philosophical Transactions for 1862, but for some reason, probably insufficient intensity of the condensed induction spark, his pictures do not bring out the peculiarities of the various metals in the striking manner that is both necessary and attainable."—("On Diffraction Spectrum Photography and the Determination of the Wave-lengths of the Ultra-Violet Rays."—"Nature," 1874, Vol. xi., p. 224.

M. Cornu has given a description of the solar spectrum from the line called *h* to the ray O, and has drawn a beautiful map made to the scale of wave-lengths.—(Annales de l'Ecole Normale, 1874). The spectra were observed by photography in a manner similar to that devised by M. Mascart, but as the optical apparatus was made of glass all rays more refrangible than O (wave-length = 344·11) were intercepted. In continuation of his experiments (Annales de l'École Normale, 1880,) using more perfect lenses of quartz and Iceland spar as well as prisms of these materials,

M. Cornu has succeeded in photographing the solar spectrum as far as a line called W (wave-length = 294·84). The photographs were executed with bromo-iodized collodion and ferrous sulphate developer. Comparing the spectrum with that of the solar rays, it was found that the incandescence of the metal caused by the action of fifty-five Bunsen's elements was much more intense than sunlight. The lines in the spectrum thus observed were for the most part coincident with the solar rays L, M, N, O, P, Q, S_2, T, and U, their identity was easily recognised. The ray R is due to calcium, while other important lines belong to nickel, aluminium, magnesium and titanium.

M. Cornu ascertained the wave-length of the iron lines and lines in the solar spectrum by taking photographs with a Nobert's grating ruled on quartz.

In the year 1872, I was engaged in making observations on the absorption spectra of saline solutions with a view to elucidating the nature of their constitution.—(Proceedings of the Royal Society, vol. xxii., p. 241. Proceedings of the Royal Institution. On the action of Heat on Coloured Liquids. A Friday Evening Lecture, April, 1875.)

I was then led to the examination of colourless solutions in the manner described by Miller. The original apparatus used by him was reconstructed and the best means of obtaining good results was the subject altogether of several years investigation Various difficulties and interruptions prevented a definite line of research being commenced until the close of the year 1877.

At this time I devised a method of photographing the ultra-violet spectra of metals, including on one plate, accurately focussed and sharp impressions of all lines lying between the least and the most refrangible rays capable of acting on bromide of silver. The photographs of Dr. Miller which are the only spectra of the ultra-violet region that have hitherto been published were executed with too wide a slit and are defective in being almost entirely out of focus.*

* I am not unmindful of the fact that Mr. Norman Lockyer on January 7th, 1875 (Proceedings of the Royal Society), described a new map of the solar spectrum, which he was preparing by the aid of enlarged photographs, nor that Mr. Rand Capron has published a number of excellent photographs of metallic spectra, but in neither case are rays included with a greater refrangibility than λ = 390.—(Photographed Spectra, by J. Rand Capron F.R.A.S., Spon. & Co., London). Lockyer, Phil. Trans., Vol. 164, pp. 484, 805, 1874.

Although the form of apparatus employed by me has been shown to those especially interested in the subject, yet no detailed description has ever been published, partly by reason of the fact that until the summer of 1879 only a temporary arrangement was made use of, and it was considered probable that further improvements might be effected. Constant use, however, has shown that practically it leaves nothing to be desired.

As an introduction to the publication of a series of photographs of metallic and other spectra the description of the apparatus is most appropriate.

The instruments employed are the following:—First, an induction coil guaranteed to give a five to six inch spark in air, connected with a Leyden jar, for the production of an unbroken stream of dense sparks between metallic electrodes. Second, a collimator tube ranging from fifteen to thirty-six inches in length at the end of which is a quartz lens. Third, a quartz prism capable of being placed at the minimum angle of deviation for any particular ray. Fourth, another quartz lens and the body of a photographic camera capable of being extended to the full focal length of the lens. The separate portions of the apparatus particularly if lenses of thirty-six inches focus be used, should be firmly fixed by means of screws to prevent the shifting of any part, since the proper adjustment of the whole takes some time. The coil is excited by a battery of five Grove's cells. The Leyden jar is of such a size that each surface of tinfoil measures seventy-two square inches. So far the general arrangement is that used by Miller and others, the most important difference lies in the details of construction of the camera.

Description of the Photographic Camera.—Two cameras have been in use—one designed for photographing with one quartz prism and lenses of thirty-six inches focal length (*vide* Plates 12–15), the smaller one adjustible for lenses of nine to seventeen inches focus to which prisms of various refractive and dispersive powers can be adjusted and with which two or more prisms can be used by an alteration in the prism-table. This latter instrument differs from the former chiefly in details allowing of very accurate adjustments, and of great adaptability in the collimator-tube, the prism table and the camera-body so that the requirements of the

optical parts of different construction would render unnecessary any great alteration in the apparatus.

Principles of Construction.—I will first describe the principle that guided me in the construction of these cameras, and afterwards describe their parts in detail. In working with the ultra-violet spectrum we have to take into account an effect due to the linear dispersion caused by the lenses. This is comparatively inappreciable, or at any rate so small, that in photographing the visible spectrum it can readily be corrected by the ordinary "side swing" of the back of a well-made photographic camera. To the original instrument used by Miller there was no "swing back," so that the focussing screen and photographic plate were placed at right angles to the ray which passed through the centre of lens. Hence, only this one ray could be properly focussed in any position which could be given to the photographic plate. It was found by experiment with a lens of thirty-six inches focal length for the line D, that the difference in focal length between this and one of the most refrangible rays of cadmium, namely—line 25 was about six inches. The focussing screen, therefore, was placed at such an angle that a mean position was secured for all rays lying between the two extremities of the cadmium spectrum. Having regard to what Professor Stokes has said on the subject, it was scarcely to be expected that the lines would all be perfectly in focus.

"On account of the increasing refraction by the lens of rays of increasing refrangibility, the locus of the foci of the different rays formed an arc of a curve, or nearly a straight line, lying very obliquely to the axles of the pencils coming through the lens."—(Phil. Trans., 1863, p. 605.)

Experiment, however, has proved that the locus of the foci lie so nearly in a straight line of that part of the prismatic spectrum which acts on a photographic plate, that the slightest curvature caused by the pressure of the spring which holds the plate in position in the dark slide is sufficient to throw the lines considerably out of focus.

In January, 1878, a paper by M. Sarasin was published ("Archives des Sciences Physique et Naturelles, Geneva," vol. lxi., p. 109), giving the result of his determination of the refraction

indices of quartz for the ordinary and extraordinary rays in the ultra-violet spectrum.

By the aid of a table which he gives it is possible to calculate the position that a photographic plate should take in order that any particular ray may be in focus. For future reference I quote this table in full—

Co-efficients necessary for the determination of the focal length of a quartz lens for the ultra-violet rays of cadmium, its focal length for the ray D being known.

Numbers referring to the lines of Cadmium Zinc and Aluminium.	Co-efficients.	Numbers referring to the lines of Cadmium Zinc and Aluminium.	Co-efficients.
9	0·9657	25	0·8707
10	0·9612	26	0·8632
11	0·9590	27	0·8561
12	0·9531	28	0·8498
17	0·9262	29	0·8429
18	0·9127	30	0·8363
23	0·8863	31	0·8245
24	0·8803	32	0·8062

The focal length of the lens for the line D to be multiplied by the co-efficient opposite the ray, the focal distance of which is required to be known.

From this it may be ascertained that the focal distance for a 36-inch lens would, for the cadmium line 25, be 31·3 inches, and for a 15-inch lens 13 inches.

The angle, however, at which the plate must be placed to secure a good photograph is a resultant of the refraction and dispersion of the prism, and focal length of the lens. Of the three diactinic materials of which I have had prisms constructed, Iceland spar gives greatest dispersion, quartz next, and water least. In figures A and B, Plate 15, is given a sketch of the relative positions actually assumed by the collimator tube and photographic plate when accurately focussed, the optical train consisting of a pair of 15-inch lenses, and one prism, with an angle of 60° made of water and quartz respectively in the two cases. One water prism is practically of no use for obtaining fine photographs, because the rays strike the sensitised plate so obliquely by reason of their running so nearly parallel to it that the images they produce after passing into the sensitive film, instead of consisting of sharply defined lines, take the form of exceedingly narrow bands,

which have the appearance of a line and a shadow beside it. A train of four or six water prisms, no doubt would remedy this by giving increased dispersion to the rays; but a longer exposure of the photographic plate would be necessary, on account of the strength of the rays being diminished by reflection from the many surfaces of quartz of which the sides of the prisms are made, and the apparatus would be complicated by the multiplicity of prisms.

For several reasons I prefer to employ quartz prisms. In order to ascertain the position of the plate with regard to the ray of mean refrangibility, a calculation based on the refractive power of the prism, for one of the ultra-violet lines of cadmium, as for instance line 17, as well as the focal length of the lens for this ray as compared with those constants for the line D, gives us roughly what is afterwards determined more accurately by experiment.

With a quartz prism of 60°, the angle which that half of the plate on which lies the most refrangible part of the spectrum must make with the direction of the mean ray, varies between 19° and 21°, with lenses of 15 and 36 inches focus. The camera back is therefore constructed so as ordinarily to take up this position, but it is made to swing on a vertical pivot exactly situated at its centre. The centre of this pivot is in the same vertical plane as the centre and front surface of the focussing screen, which again, as is usual, corresponds with that of the photographic plate.

It follows from this that if any particular ray situated at the centre of the plate be accurately focussed no alteration in the inclination of the plate will displace this line. The mean ray of cadmium is the line 17, and the first thing to be done in adjusting the camera is to place the prism at the angle of minimum deviation for this ray, then the ray is brought into the centre of the focussing screen and carefully focussed by a backward or forward motion of the camera body communicated by the focussing screw. After this the "side-swing" enables the extreme of both ends of the spectrum to be brought into focus. Nothing more then remains to be done but to clamp the camera-body in position.

Details of construction of the camera for lenses of long focus.—In Plates 12 to 15 the elevation and plan of this instru-

ment are seen. The body consists of two parts supported on a wooden stand. The portion M (Plates 12, 13) is a rigid shallow box, in the front of which is the lens in its fitting N. The portion of the body L, a continuation of M, is triangular in form and moveable in two directions. It is made to approach or recede from the lens by the screw K, and to make a greater or lesser angle with the direction of the mean ray $X - \delta$ by turning on the vertical pivot, the centre of which is situated at x. The two portions of the camera are united by a bellows-body of leather of about three inches in length which admits of sufficient play for all the purposes of focussing. The sensitised surface of the glass plate when in position is indicated by the dotted line $\alpha - \beta$. The screws N, N, serve to clamp the "swing-back" of the camera in position.

It will be seen in the elevation that the camera-body is raised on supports above the flat stand, but that the camera-back, into which fits the dark-slide, is continuous above and below the camera-body. This arrangement enables one to obtain several photographs on one plate by moving down the frame carrying the dark slide by means of a rack and pinion. Thus in the elevation of the camera-back which is open $C - c$ (Plate 14) is the moveable frame work, $D - d$ is the dark slide, B B are the thumb screws, and b the pinion which works in the rack on the front edge of the dark slide. The interior of the dark slide with wires for holding the corners of the sensitive plate are shown by G, g; while H, h, is the slit in the camera-back through which the spectrum is projected. E and F represent the door at back and the sliding front of dark slide respectively. In the elevation an opening I, i (Plate 12), in the body of the camera, and door to the same J through which is seen the slit H, h, by which the spectrum passes to the sensitised plate. In the act of focussing, a glass plate covered with some fluorescent substance, is placed in the dark slide and the lines of the spectrum are viewed by reflection from its surface by looking through the opening I, i.

This is the most convenient way of viewing the ultra-violet rays, as the coloured spectrum and the obscure rays are visible at the same time.

The arrangement of prism and collimator tube, the former when uncovered is shown in the elevation of the same. P (Plate 15) is the prism, S the aperture for the ordinary rays, T

the revolving prism-table, U the clamping screw for fastening the table when the angle of minimum deviation is obtained for the cadmium line 17. V is a cap to the collimator tube for excluding rays of strong light. Over this cap the prism-box is fitted having an oval opening at one side to admit of a sufficient amount of movement of the collimator tube to the right or left to secure proper adjustment. There is a round aperture opposite the lens for the passage of the refracted rays.

Care should be taken to secure prisms cut perfectly true at the base in addition to having good faces. After fixing the prism in the desired position, it is necessary to adjust the collimator tube very carefully to its proper angle, otherwise the best results will never be attained when photographing metallic lines. The collimator tube being three feet in length is placed on a separate stand. The slit end terminates in a small mahogany box with a hinged lid. At the extremity of the box the slit is fixed. This box serves two purposes; first, when the absorption spectra of volatile liquids are being examined the substance is placed in a little cell of quartz which stands in the box behind the slit, thus lessening the loss of rays. When the lid of the box is shut the liquid if excessively volatile is not inflamed by the spark, and as the vapour may fill the collimator tube, its absorptive power is readily examined notwithstanding its rapid evaporation. The second purpose of this box is to enable the experimenter to judge in what direction to move the electrodes so that the spark may exactly fall upon the slit and pass in a straight line down the collimator tube. This is done by means of a piece of card which fits just inside the box and has a vertical line ruled down its centre, when the spark is exactly opposite to the slit, the ray of light strikes the centre of the card. A tube at the far end of the collimator near the prism box about one-quarter inch in diameter and three inches long, projects upwards at right angles and serves for the introduction of gases into the tube, which may require examination. It is also necessary when examining volatile liquids to exhaust the tube of the vapours they evolve by drawing a current of air through the tube, otherwise subsequent experiments might be vitiated by the residue of a highly absorbent vapour.

The cells for holding solutions are cut from pieces of glass tube

one inch in diameter, by slicing it longitudinally in two pieces, and cutting off lengths of three-fourths of an inch. These are fitted in metal frames and pieces of quartz are affixed to each end by means of screws pressing upon a rim of metal. The cells are made water-tight simply by grinding and polishing the ends, it is not admissible to use any cement for the purpose.

Description of the short focus or portable spectroscope-camera. —The lenses of this instrument are two inches in diameter and of fifteen inches focal length. The camera-body is of the same construction as that already described, but the prism stand and collimator tube, as well as the camera-back, are fitted on to a small optical bench. This is intended to serve the purpose not only of very careful and accurate adjustments, but to secure rigidity so that the instrument may be transported from place to place, and turned about in any position without derangement of its parts. The camera-body can be altogether removed and the camera back turned round on its vertical axis by means of an Archimedian screw beneath it. When once adjusted the screws can be locked. It is, however, impossible to secure the apparatus from an accidental wrench or blow, which might, in spite of the security of the screw adjustments alter the position of one or other of the parts, it is therefore advisable to read off on scales the exact angular position of the collimator tube, the prism, and the camera. The minimum angle of deviation of the prism for any particular ray is effected by a screw movement. The slit has jaws of iridium and a micrometer screw divided into fiftieths of a millimeter.

The camera body was made by Mr. Meagher, of Southampton-row, London, the optical bench by Elliot Brothers, Strand, and the slit, prisms, and lenses, by Mr. A. Hilger, Tottenham Court-road, London.

The Photographic Process.

The original method of photographing employed by Dr. Miller was found to be defective: first, because the more refrangible end of the ultra-violet spectrum is extremely weak, if not entirely wanting, when photographed on plates containing a plain iodized collodion; secondly, a wet collodion process is disadvantageous when long exposure is sometimes necessary; and thirdly, when

working in a small room the ozone generated by the electric discharge acts upon wet collodion plates in such a manner that they become coated with a thick deposit of silver directly the developing solution is applied, the deposit being the densest where the bath solution has most accumulated. Much longer and better spectra are detained by using ordinary bromo-iodized collodion and an iron developer, but of course this process is rendered useless by the action of the ozone on the silver solution.

The extraordinary improvements made of late years in the preparation and development of dry plates, together with the foregoing facts, combined to recommend a dry process.

Successive trials have been made with plates coated with washed collodio-bromide emulsion, with the Rev. Canon Beechy's collodion emulsion plates, and with gelatine pellicle plates. The gelatine plates are to be preferred for two reasons; if they are wanted for the production of negatives to print from, the film is exceedingly fine and even in texture, and on the other hand, if transparencies showing absorption bands are desired they need not be varnished. The Beechy plates are more sensitive to very feeble rays in the more refrangible part of the spectrum than those coated with gelatine pellicle; this may be seen by comparing the spectra of iron photographed on these two varieties of plates. One advantage of the gelatine plates is that they photograph more of the less refrangible rays than any others, and though the lengthening of the spectrum in consequence is comparatively slight, yet it is of importance in the examination of certain coloured substances, which while they transmit rays of higher refrangibility absorb the blue and violet. Such bodies are solutions of the nitrophenols and nitranilines. The exposure of the sensitive plates has varied with the long-focus camera from three seconds to an hour and a half, according to circumstances, depending partly on the plates employed and the object to be attained; but it is seldom that a longer period than one or two minutes is necessary even for the production of negatives to print from, and when photographing absorption spectra with an open slit three seconds will suffice. The exposure is four times as rapid with the portable camera with lenses of fifteen inch focus.

The method of development preferred before all others, is that originally described by Mr. B. J. Edwards.

The materials consist of two stock solutions, the compositions of which are as follows:—

No. 1.—The Developer.

Pyrogallic acid, ...	$\frac{3}{4}$ ounce.
Glycerine, ...	1 „
Methylated spirit, ...	6 „

No. 2.—The Accelerator.

Potassium Bromide, . . .	60 grains.
Ammonia sp. gr. ·880, . . .	1 ounce.
Glycerine, ...	1 „
Water, ...	6 „

The solutions before use are each diluted with fifteen volumes of water.

To develope a plate, mix equal volumes of No. 1 and No. 2, pour the mixture into a dish, immerse the plate, and rock the dish gently. According to the nature of the sensitive films, less or more of solution No. 2 may be taken. The development should proceed without any forcing or local development, and be completed in two minutes. The spectral lines should remain dense and black after fixing.

Mr. Carey Lea's developing solution is made by boiling an excess of ferrous oxalate with 100 grains of neutral potassic oxalate and 1 ounce of water. Or the following proportions may be used:—

Ferrous oxalate, ...	1 part.
Potassic oxalate, ...	4 „
Water, ...	16 „

To each ounce of the above solution is added 1 drachm of a solution of 40 grains of potassic oxalate per ounce of water.

From photographs recently taken it appears that the pyrogallic developer acts more equally upon all portions of the spectrum while the ferrous oxalate solution developes the image rather more strongly at the less refrangible end. At first I was much astonished to find that this could be the case, but a little consideration of the different behaviour of these two developers affords an explanation of how it is possible.

When a deposit of silver has been made in an exposed film by immersion in ferrous oxalate solution, particles of silver bromide are reduced in increasing proportion with the length of time that the plate is left in the developing solution. The group of air lines at the less refrangible end is, as a rule, the most active portion of a spectrum. Hence, when the exposed plate is put into the developer, they appear sometimes half a minute at least before the more refrangible rays are visible. They get, therefore, half a minute start—so to speak—of the rest of the spectrum and the larger the deposit of silver upon them the greater will be the rate of reduction of fresh particles. With the pyrogallic developer the action is different; there is not a progressive rate of reduction of silver bromide, increasing with the length of period of immersion in the solution; hence, though the less refrangible rays are first rendered visible, their development soon ceases, and that of the other portions of the plate which have been more slowly acted on become developed to an extent which differs but little from that of the air lines.

After the development of the plates they are washed and steeped for some time in a solution of alum. Subsequent and final washing is carried on in a stream of water for several hours. Very thorough washing should be regarded as essential, otherwise gelatine negatives are apt, after a period varying from three months to two years, to become yellow or to fade. Negatives are the better for a coat of varnish, which may be a hard photographic varnish diluted with once to twice its volume of strong alcohol.

The Optical Train.

It is a remarkable fact, as pointed out by Miller, that all the materials which enter into the composition of glass are of much greater transparency to the photographic rays than glass itself. As for instance quartz, Iceland spar, and rock-salt; likewise, also, is alum very diactinic. The small amount of iron which is found in specimens of crown glass was supposed to be the cause of the difference. In the hopes of finding a glass nearly, if not quite as diactinic as quartz, I have at various times examined samples of great purity made by Feil, in Paris, and others, but in no case have I met with a material suitable for the examination of ultra-violet spectra. The disadvantage attending the use of quartz and

Iceland spar arises from the difficulty in getting rid of the effects caused by double refraction.

Beautiful results can be obtained by the use of hollow prisms filled with water, their sides being made of thin plates of quartz; but it is necessary to have more than one prism, otherwise the lateral dispersion is not sufficient to enable one to focus accurately more than a very limited portion of the spectrum.

The prisms which I am now using are of quartz, and corrected in a manner for double refraction, which was kindly communicated to me by letter by M. Cornu. The double refraction which is noticed as affecting the lines of metallic spectra as photographed, is caused by circular polarization, causing the ray to be turned to the right or left. To obviate this each prism, with an angle of 60°, is composed of two equal halves—one cut from right-handed, the other from left-handed, quartz. Optical contact between the faces is secured by means of a thin layer of glycerine or of pure water. The lenses, in the same way, are cut to correct each other. In the case of those of long focus—36 inches—they are both doubly convex, but the short focussed lenses are plane convex.

In photographing absorption spectra the slit of the instrument is wide open, but of course this is inadmissible in the case of line spectra. The width of the slit is then narrowed to $\frac{1}{500}$th of an inch or thereabouts, and as some difficulty is experienced in keeping it free from dust, it has been found convenient to cover it with a thin plate of quartz, which can of course be kept clean by simply wiping it with a leather.

XI.—ON THE THICKNESSES OF THE IRISH BEDDED ROCKS, BY G. H. KINAHAN, PRESIDENT ROYAL GEOLOGICAL SOCIETY, IRELAND. PLATES 7 AND 8.

[Read, November 15th, 1880.]

In these diagrams, which I now exhibit (*vide* Plates 7 and 8), the thicknesses are probably less than they would be represented by most geologists; they have been, however, calculated with great care, and in all cases where there was possibly a repetition of beds by faults allowance has been made for this, and in those groups which are of variable thicknesses only the mean thicknesses are given. The bedded eruptive rocks which occur at particular zones are included in the thicknesses.

In the right hand margin of the diagram full particulars are given as to the localities where the different strata occur and when they are best represented—and the zones in which remarkable fossils, coals, eruptive rocks, &c., are found. In the left hand margins the thicknesses of the strata are shown.

[NOTE IN PRESS.]—The sections of the Silurian rocks in N. E. Mayo to the north-westward of Ballaghaderreen, and in Tyrone to the eastward of Sixmilecross are very similar; having below and above, red rocks of the "Dingle beds" type, with between them green rocks containing subordinate shales and impure limestones. These calcareous rocks of the Co. Mayo have in them marine fossils, but as yet it has not been positively proved that they occur in the similar rocks of the Co. Tyrone.

N.B.—Owing to an error, the scale on Plate VII. is given as 25,000 feet to one inch, it should be 2,500 feet to one inch.

XII.—ANNIVERSARY ADDRESS TO THE ROYAL GEOLOGICAL SOCIETY OF IRELAND, BY G. H. KINAHAN, M.R.I.A. PRESIDENT.

[Read, February 21st, 1881.]

Before proceeding with the special subject to which I wish to call your attention at this, our Anniversary Meeting, I have to record the departure from amongst us of two Ex-Presidents of our Society.

Charles William Hamilton, M.R.I.A., F.G.S., died on February 16, 1880, the very day of our last annual meeting, at an advanced age. He was one of the original members of our Society, and sometime Secretary, and also President thereof in 1845 and 1846. He was an energetic and well-known field-worker in our Science, at a time when there was no published Geological Map of Ireland to assist the explorer, and has contributed numerous papers to our "Journal." He took an active part in discussions respecting certain formations whose relations were of necessity imperfectly understood, before the extensive induction of facts, which we now owe to the Geological Survey had been made. If he was, as we must believe, unquestionably mistaken as to the age of the rocks forming the mountains between MacGillicuddy's Reeks and Kenmare, we must remember that Sir Richard Griffith and Mr. Jukes, who both disagreed with him, likewise disagreed with each other on the same point; and the question cannot be said to be definitively settled even yet. On the other hand, we must not forget to mention that it was Mr. Hamilton who first pointed out to Sir Richard Griffith, in 1836 (see Phil. Mag., Dec. 1839, p. 444), that the roofing slates at Ringabella Bay, south-eastward of the city of Cork, were really newer than the Old Red Sandstone strata to the north of them. These, from their very ancient appearance combined with the concealment of their junctions with the O. R. S., had been regarded by several eminent geologists as belonging to the "Older Transition" formation, or in modern language as being either Lower Silurian or Cambrian. Mr. Hamilton's bold innova-

tion was afterwards amply confirmed by the discovery in that rock-group of Carboniferous fossils. Mr. Hamilton has set an example which I could wish to see more often followed by geologists in displaying concern for the antiquarian remains of Ireland. During the investigation of the cairns on the Lough Crew hills, in 1865, Mr. Hamilton rendered great assistance, not only by the supply of workmen, but also by personal inspection, and in consequence the marked thanks of the Royal Irish Academy were returned to him for his valuable services on the occasion.

It is with the deepest feeling of regret that we have to record an event which, however, must have taken place before long in the ordinary course of nature, and that is the death, on January 17, 1881, at the ripe age of 82 years, of the venerated Humphrey Lloyd, D.D., D.C.L. (Oxon.), LL.D. (Cantab.), F.R.S., Provost of Trinity College, Dublin. This is a feeling in which all present will share, not only as those who can prize high moral worth and intellectual capacity, but also as Irishmen who can be proud of a distinguished fellow-countryman, and also as members respectively of the two associated Societies of which this is a joint meeting. Dr. Lloyd had been President of the Royal Geological Society of Ireland in 1863 and 1864, and at his death was still Vice-President thereof and of the Royal Dublin Society. He was an original member of the Geological Society, which was established in 1831; his father, Dr. Bartholomew Lloyd, was our first President and as such gave the opening address to the Society in February, 1832. Our late distinguished Ex-President did not make geology a special subject of his attention, although taking a great interest therein; nevertheless the three lines of physical research which he more particularly prosecuted bear more or less strongly on our science.

The first we shall mention is that of Optics. He has left two important works on that subject, viz., A Treatise on Light and Vision, 1831, and lectures on the Wave Theory of Light, besides various papers in the Transactions of the Royal Irish Academy and elsewhere. He it was who was selected to draw up the "Report on the Progress and Present state of Physical Optics" for the British Association in 1834. Physical Optics bears directly on the subject of Crystallography, which belongs to Mineralogy, which, in its turn, is really part of the comprehensive science of Geology; and therefore we find most appropriately inserted in

our Journal a paper, or lecture, communicated to the Society in 1836 by Dr. Lloyd, "On the Optical Properties of Crystals and their relation to the Crystalline Forms." In connection with this we cannot refrain from mentioning now, though it has been so often referred to in various books and papers, the delicate and successful investigation by which Dr. Lloyd verified the prediction of Sir William Rowan Hamilton respecting Conical Refraction in biaxial double-refracting crystals. Sir William, from his discussion of Fresnel's theory, perceived that when a ray of light has traversed a biaxial crystal in the direction of either of the lines of *single ray-velocity* (which lines nearly coincide with the optic axes of the crystal) the linear ray, on emergence, becomes refracted into a cone of rays; this he called external conical refraction. He perceived also that there must be another case of this phenomenon viz., internal conical refraction, which must take place when a ray falls on the crystal so that one of the refracted rays would, according to the usual law, coincide with an optic axis; this ray on entering the crystal must be refracted into a cone, which on emergence would become a cylinder. Dr. Lloyd, seeing that arragonite would be specially suitable for the purpose on account of the comparatively large angle between its optic axes, selected that mineral for experiment and satisfactorily proved the correctness of both anticipations of Sir W. Hamilton, thereby contributing to a very remarkable triumph of mathematical investigation and corroboration of the undulatory theory of light.

Another physical subject which was a speciality of Dr. Lloyd's was that of Magnetism. He was an early and prominent investigator of the phenomena and laws of terrestrial magnetism, and it was through his influence that the Magnetical Observatory at Trinity College was established in 1838. He was largely instrumental in prevailing upon the Government in the same year to send an expedition to the Southern hemisphere for magnetic research; and he and General Sabine were deputed by the Royal Society to go to the continent of Europe to organize magnetical observation there. On this subject he has written "An Account of the Magnetical Observatory at Trinity College, Dublin," 1842, "Dublin Magnetical and Meteorological Observations," 2 vols. 4to., 1865–9, "A Treatise on Magnetism General and Terrestrial," 1874, and numerous papers on the subject in the Transactions and

Proceedings of the Royal Irish Academy, the Reports of the British Association, and various scientific periodicals. The terms "terrestrial magnetism" and "earth currents" at once suggest the reason why geologists are interested in his labours in that line. The part played by magnetism as a geological agent is still very imperfectly understood, but we have already some intimations of it; this form of energy is mentioned by Dana among the causes of events in the earth's geological progress, and as one the laws of which the geologist cannot know too well. Judging from experience we cannot doubt that increased knowledge will, in the course of time, render the magnetical researches of Dr. Lloyd available for the elucidation of various geological problems in a way and to an extent that we cannot now divine.

A third subject which largely occupied the thoughts and time of Dr. Lloyd was that of Meteorology, which is perhaps still more closely connected with geology than either of his two other pursuits. Dr. Lloyd was one of the first scientific men who perceived the importance of ocean currents as heat carriers and effective agents in modifying climates, and was a firm believer in the view first put forward by Sir John Herschel that, in order to account for changes in geological climates, it would be found necessary to take account of secular changes in sun-heat as well as of local alterations in terrestrial conditions. Dr. Lloyd's masterly discussion of the Meteorological Observations made in Ireland, in 1850–1, by the Royal Irish Academy, marked an epoch of decided advance in the treatment of meteorological data.

In his Presidential Address to the British Association, at its meeting in Dublin, in 1857, Dr. Lloyd did not fail to give to geology its due share of notice. But, as we have seen, independently of the fact of his direct interest in our science he was a powerful and helpful ally thereof. In the two fields of research last mentioned he was dealing with cosmical forces which affect both generally and locally the body of our globe. This is a region of discovery into which geology is being ever more and more compelled to extend her outlook, and she is thankful for all light obtained from thence, not being able to work therein for herself. But we must not forget the reflex action between geology and other lines of investigation of nature, of which we have just had an illustration in the matter of sun-heat, not to mention others

that might be instanced; in respect of this the scientific labours of Dr. Lloyd contribute to vindicate her dignity and her status among those other lines of research by showing that they may be in their turn indebted to her for important and unlooked-for suggestions and indications.

WASTE LANDS OF IRELAND.

THE subject which I propose now to consider may perhaps be regarded by some as not of a sufficiently geological characte to be suitable to the present occasion; yet when we consider that it relates to the practical application of geology to a matter of vital importance to the country, and that I am not only addressing the members of the Royal Geological Society of Ireland, but also those of the Royal Dublin Society, a society one of whose principal objects is the development of the resources of the country, the subject of the cultivation of the WASTE LANDS of Ireland may not appear to be so much out of place.

The connexion between geological phenomena and agricultural interests is illustrated by the fact that the boundaries of better and worse land, on Griffith's Map of the Soils of Ireland, agree very nearly as a general rule with the boundaries of the different petrological groups. It was in consequence of this connexion that the small edition of Griffith's Geological Map of Ireland was issued to accompany the instructions to the land valuators, and to assist them in their work. There are, however, important exceptions to the just mentioned agreement between the boundaries of lands of different qualities and different rock formations; these, however, illustrate in their own way the same general principle; as, for instance, where "limestone gravel" has been carried by geological agencies on to granite districts, producing there what would be taken for a limestone soil; or where shale or schist gravels and clays have been carried over sandstone areas; or where sandstone detritus has moved on to limestone areas, producing a soil inferior to that which would be derived from the local rock formation.

I wish to point out on the present occasion, as briefly as possible, how a knowledge of nature's laws, as far as they come within the cognizance of Geological Science, combined with the experience

and skill of engineers and agriculturists, may be utilized in improving the unproductive or waste lands of the country.

These unproductive lands may be generally classed as *Flooded Lands* either by the sea, lakes, rivers, or streams; *Lowland, or Red Bogs; Mountain Bogs; Mountainous tracts; Upland Wastes,* and *Blown Sands.*

A saying of the great Nimmo, often repeated in the west of Ireland, was—"Give me money and men, and I will make a road across Dingle Bay." Whether it be true or not that nearly everything is possible to the engineer, in the matter of the in-taking of land we have very seldom to consider the possibility or impossibility of the work to be done, but only by what means it can be carried out at the least expense, so as to be at the same time perfectly effective and profitable; and it is here that the geologist can help the engineer.

As to the reclamation of lands flooded by the sea—the kind of sea-wall that would be likely to suggest itself, on first thoughts, is a structure, which from its simple massiveness would be able to resist the advance of the sea by main force and keep it back. But such a barrier would be necessarily very costly, and we find, after a study of the subject, that a judiciously planned and cheaper defence may be far better. First, then, as to the construction of the wall itself; as I pointed out in a paper read before the Institution of Civil Engineers of Ireland, steep rocky shores present conditions which are favourable for the waves dashing up to greater or less heights; while sands, shingles, and the like, absorb, as it were, and destroy the force of waves; more especially when a beach slopes at different angles. This subject has received considerable attention from the Dutch engineers, who now make their embankments after the best natural form, that is of slopes and flats (cesses) combined. Thus they are enabled to break the force of any wave. They have also learned that nearly any materials will do for the body of the bank (they generally use the sand from outside the embankment), as its stability depends principally on its faces; these they make staunch, not by heavy stone work (except under peculiar circumstances) but with clay, wood, fascines, and the like, as the face of the bank is generally only for a temporary purpose, that is, to preserve the structure while a strand is being banked up against it by tidal or other

currents; and if a strand does not collect outside, they force it to do so by the judicious erection of groynes.

Full details respecting these banks will be found in the writings of the Dutch engineers.

Now, as to the assistance which the geologist can give in the matter of laying out sea-banks. The travelling of sea-beaches and the denudation of coast-lines and other related natural operations are phenomena which come within the range of observation of the geologist, and which he is specially drawn to study, as they bear so strongly on various questions of physical geology with which he is concerned. The knowledge of such operations of nature is indispensable for the proper laying out of embankments and for the arrangement and effective placing of groynes. The latter are most important defences against the sea, not only in protecting embankments, but also for the preservation of the coast in those places where the sea is encroaching and slowly destroying good land. Many of the Irish intakes which have been successful in keeping out the sea, are not as profitable commercially as they would have been if so much money had not been unnecessarily sunk in making the embankment and if groynes had been judiciously employed.

The catchment drains and canals of many of the Irish intakes are defectively planned for want of the study of the nature of floods in rivers and streams. The laws of floods teach us that ordinary floods occur nearly every year, extraordinary ones at intervals of about twenty years, while some of very excessive violence may occur at greater intervals. In disregard of these facts the catchment drains and their appurtenances are usually only calculated to meet the requirements of ordinary floods; and extraordinary floods when they come are always more or less disastrous to the undertaking. To meet the requirements of extraordinary floods, and to give them a sufficient waterway, it is expedient that the banks of the drains should be at some distance from them, and that the bridges be sufficiently capacious.

A knowledge of chemico-geology is necessary to bring the intaken lands into cultivation; this, however, is a subject of such vast extent that it cannot be considered now.

To cultivate lands flooded by lakes it is necessary to drain the lakes more or less. If a lake is only partially drained, the form,

position, and size of the embankments must be determined by a knowledge of the action of wind-waves; and in all cases the catchment drains should be made to meet the requirements of *extraordinary floods.*

For the improvement of *corcasses* and *callows,* that is the low flooded lands adjoining estuaries and rivers, the size, form, and position of the embankments should depend on the nature of the floods to which the estuaries or rivers are liable; making careful provision for extraordinary floods. This point is often neglected, the banks being made as close as possible to the margins of the estuaries or rivers, thus leaving no room for the waters of excessive floods.

Formerly flooding with "dirty floods," or what is called in the valley of the Trent and other places in England "warping," was extensively practised in Ireland to enrich the callows and raise their levels. This has been discontinued in many places; but it might be profitably resumed in the cases of both upland and tidal rivers. In the county Tipperary, adjoining the Little Brosna, I changed altogether the nature of some callow land by cutting off from it the "Black flood" (boggy water) and warping it with "Red floods" (muddy water) of the Little Brosna; and the same thing might be done in numerous other cases. Dirty tides might similarly be utilized, if judiciously let on to the corcasses. This was well illustrated about twenty-five years ago when the Lower Shannon broke into the corcasses below the city of Limerick; for although great damage was done at the time, yet the flooding was allowed to have greatly improved the meadows; and the same thing has been found when excessive tides have broken the banks in the estuaries of the Barrow and other rivers.

In many places there are facilities for warping intakes from the sea, lakes, or rivers with muddy or otherwise fertilizing waters. Warping with sewage is an expedient greatly, if not entirely, neglected in Ireland. It has been done, indeed, in a small way, on a few farms, the farmyard and house sewers being discharged over meadows; but it is neglected in connexion with towns. Dublin, Belfast, Cork, Limerick, and other towns are most favourably situated for changing tracts of slob-land and sands into rich and fertile meadows, if only their sewage was utilized, instead of being turned into the sea to drive away or kill the fish.

We now pass to the Bogs. Of these, those most capable of quick improvement are the flat or flattish bogs in the mountain valleys, and next to them the great Lowland or Red bogs;* these require different treatment, as their nature is, in some respects, dissimilar. The former are usually more or less firm; while the latter have nearly always a soft upper stratum, often over six feet in depth. These differences are due to their mode of growth; the red bogs accumulating almost entirely by organic growth and decay; while during the growth of the flat bogs in mountain valleys foreign peaty matter is drifted on to their surfaces, by wind, rain, runlets, and the like.

Ordinary vegetable soil is due to the growth and decay of vegetable matter mixed with a nearly equal or a greater quantity of mineral substance; the latter being brought up from below by earthworms and other burrowing animals, in addition to what is carried on to the surface by wind, rain, and runlets, or by being deposited from the atmosphere. But bog is a peculiar variety of vegetable soil, as it is formed from excessive vegetable growth and decay, due to superabundant moisture, and has in it little or no admixture of foreign substances; it is more or less like a sponge saturated and swelled up with water. Therefore to improve bog it is necessary to ged rid of the water, destroy its sponge-like character, and add to the upper portion as much mineral matter as will bring it more or less near to an ordinary soil; all of which must be done gradually.

The mountain-valley flat bogs, being of tolerable consistency, are usually easy of cultivation. Small holders of land ordinarily mark off a patch of a size that they can "come at" or bring into cultivation in the period of three or four years. This is fenced round in the autumn or winter by a ditch, which "saps" or "soaks" the bog, and in the spring a portion is laid out in beds and planted with potatoes. With the potatoes, lime, if procurable, and farmyard manure are best; but where seaweed is plentiful it is much used, or "shell sand." Twenty-five years ago the latter was a very favourite manure for "taking in" bog; and large fleets of boats were employed in dredging the sand in

* The "red bogs" are very variable in character, some being much worse than others. In contradistinction to the typical "red bog," pastural portions are commonly called in Ireland *Baun* (anglice, *white*).

the Cork and Kerry bays; the sand was carted inland for miles, even across the mountains into the county Limerick. If the first crop is to be turnips, seaweed is an excellent manure.

It is not an uncommon practice in some places, to cut turf in the furrows after the potatoes are planted; thus additionally draining the peat and deepening the soil. When possible, some carry clay or the like to earth the potatoes; an excellent plan, as it adds to the fertility of the peat. The beds or ridges are laid out of such a width that in three years the whole of the plot has been successively in furrows; thus all the surface of the bog, for a depth of eighteen inches or more, has been disturbed and deprived of its spongy character. The potato crops of the second and third years are usually better than that of the first.

Large cultivators seem now to approve of liming, or, as it is called, "boiling the bog," as it gives the quickest return; but to make permanent grass land of a bog it must be continually top-dressed with gravel, clay, marl, pounded up limestone, or some substance that will add weight; otherwise it will crack in the heat of the summer, then form "tussocks" and eventually revert to bog land. Pounded or crushed limestone, or half burnt lime, which is used by some, is more advantageous than quick lime, because although the latter gives quick return, the others last longer in the soil. Such bogs, if to be cultivated, or "taken in" on a large scale, would require a regular system of drainage; while the spongy nature of the whole tract could be destroyed in one or two years by using a grubber; the plough would be used in place of spade labour.

In the fens of Cambridgeshire there is, in places, good deep corn land over bog from fifteen to twenty feet deep, which has been brought into its present condition principally by the addition of pounded chalk and chalk gravel, and by warping. In many places, as in the counties of Tipperary and Clare, warping might be advantageously employed in the improvement of this kind of bog, by turning on to them, during floods, the thick muddy streams from the hills and uplands; even the streams that only bring down gravel and sand would be beneficial, as proved in many mountain valleys, where a natural warping goes on; such materials carried down by a torrent changing the surface of a bog into pasture. I have noted a remarkable instance of this in the mountains near

Killaloe. A heavy rainfall of one winter, having taken possession of a cart track and cut it over five feet deep, carried the debris, slaty shingle, down and spread it over the surface of a flat bog, thus quite changing its nature. In places, in the county of Wicklow, the farmers warp on a small scale by turning the torrents loaded with granitic sand onto the boggy slopes.

The lowland or red bogs would not be as easily brought into cultivation, especially the soft ones (monegay or flow bogs); because to get rid of the water, deep and extensive drainage is necessary. Some of the extensive improvers and cultivators in Ireland are of opinion that the reclamation of these would be unprofitable. Yet what said William the Third's Dutch settlers? "Give us our own law of empoldering and we will reclaim the Bog of Allen;" and what they could do, we should be able to do. Furthermore, the surfaces of deep bogs have been made good and sound land, on a considerable scale, in England and in Holland, and, on a small scale, in the "bog gardens" on most of the Irish bogs. The Cambridge bogs, as already mentioned, were improved by adding limy matter and warping; the Dutch have largely employed the latter; while for the portions of the Irish bogs which have been changed into good tillage land, "corn gravel" (clayey limestone gravel), marl, and road stuff (pounded limestone), have been used. In a few places that I have noted, warping seems to have been carried on in former years; but I am not aware of any place at which it is practised at present. Around, and even within, the different red bogs there are plenty of materials to improve them. These are the limestone gravels in the eskers, and the gravelly clays in the mounds of Boulder-clay-drift; while in many cases they might be warped from the numerous rivers and streams.

The improvement and bringing into successful cultivation of all the Red, or Lowland Bogs, would be a vast undertaking; yet I am convinced most of them could be made good land at a cost that would eventually prove the speculation a good one; but more especially if the improvement of the surface was combined with the manufacture of the peat into an economical fuel, that is a fuel of small bulk and having its heating properties concentrated; this, however, is a subject that could not be fully treated here; but to bring into proper cultivation the surface of the Red

Bogs would be of incalculable benefit, as it would increase the area of arable land by at least an eighth; and the statesman who carried it to a successful issue would be a real benefactor to Ireland.

The improvement of the mountain wastes is perhaps a more immediately pressing question; because, although eventually they might not be as profitable as either the intakes or the cultivated bogs, yet it could be done more quickly to meet the present hunger for land. It is essentially a geological question, and one that ought to be approached with caution, as former experience has proved that certain lands of this class, will scarcely, if ever, give a return for money expended on them. As is the case with cultivable lands, the quality of mountainous and upland wastes depends in a great measure on the nature of the underlying rocks.

Of the mountain wastes we shall first mention the bogs. Those that are on the hill-tops usually are of small value; most of them, however, may be improved for grazing purposes by surface drainage. The bogs in the mountain valleys and low portions have already been mentioned.

Considerable tracts of the drift in some of the mountain valleys are cultivated; but there are, besides, the gravels (eskers) and moraine drift hills, which in some districts, especially in parts of Munster and Connaught, have been left in a state of nature. The esker drift is nearly always capable of profitable culture by subsoiling in the first instance; while what is principally necessary in regard to the moraine drift is the clearing away the numerous blocks of stone, the draining of the hollows, fencing and planting with timber. These lands being so capable of improvement, it is at first sight a matter of surprise that they should be in their present condition; but according to tradition they were originally forest lands, and since the forests were cut down nothing has been done to them. There are large tracts of such lands in the counties Kerry, Galway, Mayo, &c., capable of being made much more valuable than they are at present; but in all these mountain tracts there are areas which it would be more profitable to plant with trees than to till.

Of the soils made up of the debris of the underlying rocks, perhaps the worst is that in quartzite and quartz rock districts. Those areas in which the rocks are solely quartzite or quartz rock

will frequently be perfectly barren. However, not all tracts of quartzite are so, as associated with such rocks will sometimes be found other schists, or the quartzite may not be pure, thus in part counteracting the bad qualities; as a general rule, such lands unless very favourably situated, as near a large town or the like, will scarcely be profitable as tillage land except in patches, but might be made remunerative if planted with trees. An instance of such ground is presented by the Government lands of the Forth Mountains, county Wexford, parts of which would pay as tillage, but the greater proportion is more suited for planting. Land of this class to be either tilled or planted, ought to be subsoiled and cleared of stones, and the low portions or hollows should be drained.

Soil made up solely of granite debris is very cold and poor and is not much improved when mixed with peaty matter; the debris of other rocks, however, when mixed with growan (rotten granite or granitic sand) changes its nature, more particularly if the foreign substance is limy matter, especially if in the condition of marl. The rich lands of Carlow, on the flanks of the Leinster mountains, owe their character, in a great measure to the mixture of granitic and limestone debris. Elsewhere are also found in granitic area patches of good land more or less due to a similar cause; as, for instance, in the Galway granite hills, on, or adjoining, accumulations of limestone drift.

The highly silicious felstones give debris more or less like quartzite and granite; tracts of such rocks are, however, of limited extent. Basic felstones and whinstones, especially the friable varieties of the latter usually weather into good and rich soils Often, however, although the soil may be good it is so thin as to be unsuitable for tillage, and the land must be used for pasture. The accompanying tuffose rocks, also, are often good soil producers. The richness of some portion of the county Limerick is due to the admixture of the debris of these eruptive rocks and limestone; while in some of the mountains, such as Slieve Partry, county Mayo, the detritus from a course of a friable whinstone or tuff forms a strip of good land. When such rocks occur in mountain regions, their debris might be profitably utilized in improving the land in their vicinity.

The soils due to the weathering of most of the highly metamorphosed rocks are in part allied to the granitic soils; but as such rocks are of different compositions and characters, the resulting soils are variable; strips of land over and adjoining calcareous and some argillaceous rocks being good, while the rest may be bad and unprofitable.

Rocks of Cambrian and Cambro-Silurian ages, which are not very silicious or highly metamorphosed, weather to a considerable depth, and in most cases their detritus is capable of being converted into profitable land by subsoiling, drainage, and liming; lime being necessary to dissolve out the iron, so prevalent in such soils; in most cases, however, the iron cannot be got rid of unless the land is drained as well as limed. Subsoiling is especially necessary in those areas where, between the surface and the solid rock, there is a "shingle" or "rubble," through which most of the soluble parts of the manures applied to the surface will drain away; if, however, the shingle is ripped up and mixed with the surface soil, these parts of the manure would remain in the land. Here it may be pointed out that the natural value of land depends not only on the soil, but also on the subsoil. A stiff retentive soil with a clay subsoil would not be of the same value as the same soil with a gravelly subsoil; while a light, friable soil with a gravelly or shingly subsoil would not be of the same value as the same soil over a retentive subsoil. In the first case the subsoil would retain moisture to the injury of the surface; while in the second there would be a natural drainage. In the third case the subsoil would drain off the moisture beneficial to the land; while in the fourth the necessary moisture would be retained. Furthermore, many subsoils contain ingredients that the surface wants; and by a judicious mixture of both, the last would be greatly improved.

Considerable areas of the land coloured on Jukes' Geological Map of Ireland as Lower or Cambro-Silurian are semi-waste and could be increased in value two, three, or four fold. I am acquainted with some such lands, on which about £8 an acre was spent in draining, liming, and tilling, thereby raising its valuation from three shillings to between twenty and twenty-five shillings.

Perhaps some of the lands that might be most profitably improved are those made up of the debris of the *Old Red Sandstone* (Silurian and Carboniferous). These rocks are principally sandstones, with which are associated a greater or less amount of shales, clay-rocks, &c. The debris of the Carboniferous Old Red Sandstone often occurs, not only on the areas of the parent rocks but also on the adjoining low grounds occupied by Carboniferous Limestone and Cambro-Silurian; consequently the extent of ground so covered is often considerably greater than that occupied by the Old Red Sandstone rocks; as in and adjoining the mountain groups of Munster, Leinster, and Connaught. These lands generally are easily improved, the principal expense consisting in clearing them of the numerous blocks of stone with which they are encumbered. The character of these lands from the agricultural point of view is similar to that of those occupied by moraine drifts; and their present uncultivated condition is due to their having been forest land 150 or 200 years ago. Hundreds of acres of these lands occur in Munster and Connaught, especially in Waterford, Cork, Kerry, Clare, Galway, Mayo, Roscommon, and elsewhere.

There are also mountainous wastes on the tracts of *Carboniferous Slate* of the county Cork; these principally require drainage, clearing of stones, and judicious planting with timber to considerably increase their value. While the *Carboniferous Limestone* hills of Clare might be made more profitable if the winter floods in the Turloughs, or flooded hollows, were preserved for summer use; this is practicable in most cases.

On the *Coal-measures* the land is usually cold and bleak, and large wastes occur, as in Cork, Kerry, Limerick, and Clare. Yet draining, planting, and tilling will make even these profitable; as has been proved in isolated places in the different areas. In the Leinster area considerable portions are in a fair state of cultivation, principally on account of the industry of the colliers. Here it has been found that certain shales, raised out of the coal pits, are most beneficial when used as top-dressing; but not all of them, as some kinds poison the land.

There are also the waste lands on the Tertiary rocks of Ulster; these, however, principally occur in areas of whinstone, a rock that has already been mentioned.

Important wastes are the blown sandhills, on different portions of the coast-line. These in a few places, as at Portrane, county Dublin, have been profitably cultivated ; but usually they are only utilized as rabbit warrens. If planted with pine, as in South France, they might be made a source of revenue.

XIII.—ON THE COMPOSITION OF THE MILK OF FORTY-TWO COWS, BY CHARLES A. CAMERON, M.D., FELLOW AND PROFESSOR OF CHEMISTRY, ROYAL COLLEGE OF SURGEONS, IRELAND.

[Read, March 21st, 1881.]

DURING the winter quarter of 1880, analyses were made of the milk of forty-two cows kept at the Government Agricultural Institution, Glasnevin, County of Dublin.

The morning's milk and the evening's milk of each cow were each analysed once; and an examination of the mixed milk of the forty-two cows was also made on the 11th December, 1880.

The results of these analyses are given in the following table. The cows, it may be mentioned, were good animals; they had from one to three crosses of the shorthorn breed. They were in the house during the period of the experiments. Their food consisted of a daily allowance, of from eight to ten stones of pulped mangels and turnips, and exhausted grain from the brewery, together with from half to one and a half stones of hay. They were, therefore liberally fed.

The figures given in the table are sufficiently numerous to warrant some conclusions being deduced from them, in reference to the average composition of cow's milk, and the limits of variability in the proportions of the different ingredients. Some conclusions may also be drawn, but with greater reserve, from them, as to the influence of age and period of lactation upon the composition of the milk.

INFLUENCE OF AGE UPON THE QUALITY OF THE MILK.

The ages of the cows ranged from four years to nine years, inclusive. If we take the two groups (1st) those aged four years and five years, and (2nd) those aged eight years and nine years, we shall find a great difference in favour of the milk of the latter, both in quantity and quality.

The eighteen cows composing the first group, were on the average, giving milk during three months; the average yield from each cow, was nine three-fourth quarts; their morning's milk contained on the average, 12·97 per cent. of solid matter, and their evening's milk, 13·58 per cent. of solid matter. On the

other hand, twelve cows aged eight years and nine years, inclusive, on the average, in their fifth month of lactation, yielded ten four-fifth quarts of milk daily, containing in the morning, 13·39 per cent. of solid matter, and in the evening, 13·96 per cent. The richest specimen of milk, save one, was yielded by a cow (No. 35) eight years old, and in the tenth month of lactation; she only, however, gave six quarts of milk the day on which a specimen of it was taken for analyses. There were only four cows aged four years, and the average composition of their milk, was—

	Per Cent.
Solids, ...	12·245
Water, ...	87·755
	100·000

Their average yield was eleven one-fourth quarts.

The superiority of the old cows in giving more and better milk, may in part be due to the fact, that it is only good milch cows that are, as a rule, kept in the dairy for several years; the young cows that give poor milk, are often put into the stall to fatten.

Influence of Period of Lactation on the Quality of Milk.

The belief that milk becomes deteriorated in quality towards the end of lactation, is not supported by the results obtained by these experiments, so far as they go. Eleven of the forty-two cows were giving milk from eight to ten months, the average yield of their milk was six four-fifth quarts, which was much below the average yield of all the forty-two cows. The total solid matter in their morning's milk, was 13·57 per cent., and in their evening's milk, 13·96 per cent.

At an advanced period of lactation milk becomes scanty in quantity, but its quality—at least as shown in the cases of the eleven cows in question—becomes on the whole improved.

Six cows were giving milk for periods less than one month. They yielded thirteen quarts daily each on the average. The solid matters in their morning's milk, were 12·70 per cent., and in their evening's milk, 13·21 per cent.

Eleven of the cows were giving milk from one to two months They furnished on the average, eleven and a half quarts per diem.

The solid matters in their morning's milk, amounted to 13·46 per cent., and in their evening's milk, to 14·12 per cent.

Five of the cows were giving milk for four months. Their yield was, on the average, ten and a half quarts daily. The total solids in the morning's milk amounted to 12·196 per cent., and in the evening's milk to 13·456.

In the following table, the amount of solids in each case is shown:—

Cows giving Milk.	Quarts yielded per day.	Per cent. of Solids in Morning's Milk.	Per cent. of Solids in Evening's Milk.
Less than one month, ...	13	12·700	13·210
During from one to two months, .	$11\frac{1}{2}$	13·460	14·120
During four months, ...	$10\frac{1}{2}$	12·196	13·456
During eight to ten months inclusive,	$6\frac{4}{5}$	13·570	13·960

Difference between the Quantities Yielded Morning and Evening.

In every instance, the quantity of milk yielded in the morning exceeded the proportion furnished in the evening. In two instances, the morning's supply was three times more abundant, and in very many cases twice as plentiful. About eight hours intervened between the milkings.

Superiority of the Evening's Milk.

Thirty out of the forty-two cows gave richer milk in the evening than in the morning, and eleven cows gave richer milk in the morning than in the evening, whilst the remaining cow's milk was equally good at both milkings. The average amount of solids in the morning's milk was 13·20, and in the evening's 13·74—a difference of 0·54 per cent. The increase in the amount of solid matters in the evening's milk was due chiefly to the larger amount of fats contained in the latter. The amount was 4·22, or 0·4 per cent. over the proportion (3·82 per cent.) found in the morning's milk. In the case of the mixed milk of forty-two cows, that yielded in the evening was richer by ·56 per cent. of solid matters, including 0·44 per cent. of fats.

AVERAGE COMPOSITION OF MILK.

The results of the analyses of the milk of these forty-two cows show that the milk of well-fed cows in houses in the last quarter of the year contains, when poorest, *i.e.*, in the morning, 13·90 per cent. of solid matter, including 4·20 per cent. of fats. On the 2nd November the mixed milk of eight cows which happened to be in the same house was analysed. One hundred parts contained:—

	Per cent.
Total Solid Matters . . .	13·90
Solids *minus* Fats	9·75
Fats	4·15
Ash	0·72

The Society of Public Analysts of Great Britain and Ireland have adopted as a standard for the poorest pure milk 9 per cent. of solids *minus* fats, and 2·5 per cent. of fats—a total of 11·5 per cent. of solids. There is little doubt that milk containing less than 11·5 per cent. is watered or skimmed. Still the results of the analyses of the milk of the Glasnevin cows prove that the milk of an individual cow may contain less than 11·5 per cent. of solids *minus* fats. In twenty-five instances the solids *minus* fats are less than 9 per cent. So far as house-fed cattle in Ireland are concerned, 9 per cent. of solids *minus* fats should be reduced to 8·5 per cent. At the same time, if the milk be the mixed product of several cows, say eight and upwards, then 9 per cent. would be a fair proportion to expect. In the mixed milk (morning's) of the forty-two cows the solid matter *minus* fats was 0·7 per cent. above the standard figure 9, whilst the average of the forty-two analyses of the morning's milk gave only an excess of 0·38 per cent. above the standard proportion.

With respect to the amount of fats I think 2·5 per cent. rather low; I am disposed to believe that it should be raised to 2·75. In the morning's milk the maximal amount of fat was 5·40 per cent. (cow, No. 39), and the minimal proportion was 2·88 (cow, No. 6). In the evening's milk the maximal amount was 6·30 per cent. (cow, No. 36), and the minimal 2·69 per cent. (cow, No. 9). The average percentage of fat in the mixed milk of the cows was 4·20 in the morning's and 4·62 in the evening's. Thus it will be seen that whilst in twenty-five instances the solids

minus fats fell below the Society's standard, in no instance did the fats fall so low as the Society's standard.

The percentage of total solid matter in the morning's milk varied from 15·50 in the case of cow, No. 17, to 11·44 in that of cow, No. 38; and in the evening's milk from 16·80 (cow, No. 36) to 11·50 (cow, No. 9).

The percentage of solids *minus* fats varied in the morning's milk from 11·78 (cow, No. 20) to 8·25 (cow, No. 38), and in the evening's milk from 11·30 (cow, No. 17) to 8·27 (cow, No. 15).

The suggestion has often been made that a standard for milk should be defined by statute. Perhaps it would be advisable to institute two standards. One might be for solids *minus* fats 8·5, and for fats 2·7 per cent. Any person selling milk below this quality should not be entitled to any defence on the ground of natural poverty of the milk. Another, and general standard, might be solids *minus* 9 per cent.—fats 3 per cent. It would be open to persons charged with having sold milk below this standard to prove that it was procured from a very limited number of cows; or they might demand that the cows should be milked in the presence of a responsible person, and a sample of the milk so obtained analysed.

A milk vendor, who was prosecuted for selling milk which I certified was adulterated, protested in court that it was pure, but that it was procured from four cows known to yield very poor milk. I suggested that the cows should be milked in presence of an officer of the court, and the milk analysed. I found that it contained 13·20 per cent. of solids, including 3·5 per cent. of fats. The milk was also analysed by the Inland Revenue chemists, Somerset House, and with identical results. They further stated that it would be necessary to add 22 per cent. of water to it in order to reduce the amount of solids, *minus* fats, in it to that present in the alleged adulterated sample, which was also analysed at Somerset House.

I think there is the strongest proof that milk, on the average, contains more than 13 per cent. of solid matters. During the last sixteen years I have examined an immense number of specimens of this liquid, and whenever I was certain that it was pure, I invariably found it to contain more than 12 per cent. of solids. I

am quite satisfied that the milk of Dublin dairy herds contains from 13 to 15 per cent. of solids.

Method of Analysis.

Ten grammes of the milk were kept in a shallow capsule in the water bath at 212° F. until thoroughly desiccated. In some instances the drying process lasted two days. The residue showed the amount of total solid matters. Ten grammes dried and pulverized were boiled in about eighty cubic centimetres of ether for several hours, an upright condenser being placed over the flask containing the ether to prevent a waste of the latter. The ether containing the milk fats in solution was filtered (a very small piece of filtering paper being used) into a light tared flask. The ether was distilled off, and the last traces got rid of by passing a current of hot, dry air through the flask and condenser. The flask and its fatty contents were then weighed. The amount of the ash was determined by igniting at a low temperature in a platinum dish the residue obtained by evaporating ten grammes of the milk to dryness.

It is, perhaps, in part owing to the great care taken to extract every particle of the fat that such high per-centages of that ingredient were obtained.

In every instance the amount of solids was determined by means of two independent experiments. Many of the weighings of the fats and ash were repeated.

[Tables.

COMPOSITION of the MILK of each of FORTY-TWO COWS kept at GLASNEVIN MODEL FARM in 1880.

—	Age of Cows in Years.	No. of Months giving Milk.	Quarts of Milk yielded by each Cow.			100 Parts of the Milk contain :—									
						Morning's Milk.					Evening's Milk.				
			Morning.	Evening.	Total.	Water.	Solid Matters.	Solids minus Fats.	Fats.	Ash.	Water.	Solid Matters.	Solids minus Fats.	Fats.	Ash.
1	4	¼	8	4	12	88·00	12·00	8·90	3·10	0·65	86·98	13·02	9·02	4·00	0·66
2	4	¼	10	6	16	88·30	11·70	8·81	2·89	0·61	87·30	12·70	9·20	3·50	0·62
3	4	2	7	4	11	87·20	12·80	8·90	3·90	0·67	85·89	14·11	9·01	5·10	0·70
4	4	2	6	2	8	87·52	12·48	8·98	3·50	0·70	86·31	13·69	9·19	4·50	0·70
5	5	¼	7	4	11	85·58	14·42	10·23	4·19	0·80	84·78	15·22	9·68	5·54	0·78
6	5	¼	9	5	14	88·10	11·90	9·02	2·88	0·61	87·40	12·60	8·60	4·00	0·64
7	5	½	6	3	9	86·70	13·30	9·40	3·90	0·78	86·58	13·42	9·48	3·94	0·78
8	5	1	9	5	14	88·15	11·85	8·65	3·20	0·68	87·40	12·60	8·60	4·00	0·74
9	5	2	6	3¾	9¾	87·27	12·73	9·24	3·49	0·72	88·47	11·53	8·84	2·69	0·65
10	5	2	8½	4½	13	86·20	13·80	9·10	4·70	0·72	84·92	15·08	10·08	5·00	0·75
11	5	4	8	4¾	12¾	87·54	12·46	8·96	3·50	0·72	86·00	14·00	10·19	3·81	0·70
12	5	4	4	2	6	87·30	12·70	8·60	4·10	0·65	88·10	11·90	8·20	3·70	0·63
13	5	5	4	2½	6½	86·20	13·80	9·60	4·20	0·75	86·22	13·78	9·58	4·20	0·72
14	5	5	7	4½	11½	87·80	12·20	8·90	3·30	0·75	85·90	14·10	10·00	4·10	0·63
15	5	5	4	2	6	87·70	12·30	8·65	3·65	0·65	87·60	12·40	8·27	4·13	0·65
16	5	6	5	2	7	85·70	14·30	9·70	4·60	0·80	84·67	15·33	9·73	5·60	0·78
17	5	8	4	2	6	84·50	15·50	11·10	4·40	0·78	84·50	15·50	11·30	4·20	0·78
18	5	8	3	1	4	86·68	13·32	9·62	3·70	0·78	86·60	13·40	9·70	3·70	0·77
19	6	1	7	4	11	86·92	13·08	9·18	3·90	0·68	85·91	14·09	9·19	4·90	0·69
20	6	1	6½	4½	11	84·92	15·08	11·78	3·30	0·69	85·05	14·95	9·93	5·02	0·65
21	6	1	3	4	7	85·75	14·25	10·75	3·50	0·73	85·70	14·30	10·78	3·52	0·80
22	6	8	2	1	3	86·68	13·32	8·62	4·70	0·73	87·52	12·48	8·48	4·00	0·74
23	6	8	5	3	8	86·12	13·88	9·28	4·60	0·70	85·49	14·51	9·51	5·00	0·68

Composition of the Milk of each of Forty-two Cows kept at Glasnevin Model Farm in 1880—*continued.*

—	Age of Cows in Years.	No. of Months giving Milk.	Quarts of Milk yielded by each Cow.			100 Parts of the Milk contain:—									
						Morning's Milk.					Evening's Milk.				
			Morning.	Evening.	Total.	Water.	Solid Matters.	Solids minus Fats.	Fats.	Ash.	Water.	Solid Matters.	Solids minus Fats.	Fats.	Ash.
24	6	10	4¼	2¼	6½	88·34	11·66	8·68	2·98	0·61	86·00	14·00	10·02	3·98	0·68
25	7	4	7¼	5¼	12½	88·52	11·48	8·50	2·98	0·62	85·74	14·26	10·24	4·02	0·72
26	7	4	8	5	13	87·10	12·90	9·40	3·50	0·70	85·68	14·32	10·42	3·90	0·68
27	7	5	6¼	4	10¼	86·94	13·06	9·66	3·40	0·75	87·34	12·66	9·00	3·66	0·70
28	7	6	7	4¼	11¼	86·17	13·83	8·78	5·05	0·72	87·00	13·00	8·75	4·25	0·65
29	7	7	7	3	10	85·20	14·80	10·80	4·00	0·77	85·90	14·10	9·90	4·20	0·77
30	7	10	5	3½	8½	87·20	12·80	8·80	4·00	0·69	87·40	12·60	9·00	3·60	0·68
31	8	¼	10	6	16	87·10	12·90	9·21	3·69	0·67	87·71	12·29	8·23	4·06	0·68
32	8	1	8	6	14	87·20	12·80	8·80	4·00	0·66	87·00	13·00	9·30	3·70	0·67
33	8	7	5	3	8	87·68	12·32	9·12	3·20	0·69	87·18	12·82	9·16	3·66	0·70
34	8	8	5½	2¾	8¼	85·74	14·26	10·14	4·12	0·75	87·34	12·66	9·06	3·60	0·80
35	8	10	4	2	6	84·80	15·20	10·00	5·20	0·78	84·05	15·95	10·69	5·26	0·81
36	9	1	8½	4¼	12¾	85·70	14·30	10·64	3·66	0·80	83·20	16·80	10·50	6·30	0·68
37	9	1	10½	4½	15	85·09	14·91	9·51	5·40	0·71	84·85	15·15	9·73	5·42	0·68
38	9	4	8¼	4	12¼	88·56	11·44	8·25	3·19	0·63	87·20	12·80	9·30	3·50	0·70
39	9	5	8	5	13	86·79	13·21	9·53	3·68	0·78	86·38	13·62	9·52	4·10	0·79
40	9	8	8	4¼	12¼	87·30	12·70	8·95	3·75	0·70	86·54	13·46	9·56	3·90	0·73
41	9	8	3	2	5	87·40	12·60	9·10	3·50	0·78	85·20	14·80	10·77	4·03	0·69
42	9	9	5¼	3	8¼	85·90	14·10	10·15	3·95	0·72	85·80	14·20	10·21	3·99	0·72
Averages,			6·37	3·63	10·	86·80	13·20	9·38	3·82	0·71	86·26	13·74	9·52	4·22	0·708
Mixed whole Milk of Forty-two Cows,						86·10	13·90	9·70	4·20	0·73	85·54	14·46	9·82	4·64	0·727
Strippings of Forty-two Cows,						84·00	16·00	9·58	6·42	0·80	83·45	16·65	9·54	7·11	0·797

XIV.—ON THE RECENT REMARKABLE SUBSIDENCES OF THE GROUND IN THE SALT DISTRICTS OF CHESHIRE,

BY PROFESSOR EDWARD HULL, LL.D., F.R.S., DIRECTOR OF THE GEOLOGICAL SURVEY OF IRELAND.

[Read, 21st March, 1881.]

THE author referred to the recent remarkable subsidences which had taken place in the neighbourhood of Northwich, in Cheshire, accounts of which had appeared in the newspapers, and the causes of which were little understood. Having become well acquainted with that part of England some years since, when connected with the Geological Survey of Great Britain, he ventured to offer some explanation of these locally alarming occurrences, which he hoped might not prove unacceptable.

The district where the subsidences had occurred is a nearly flat plain, from 100 to 200 feet above the sea level, traversed by the valley of the Weaver and other streams, composed of the formation known as the New Red Marl, and overlaid at the surface by a few feet of Drift sand or clay. The Red Marl formation is the well known depository of beds of rock-salt in the British Isles, owing to which it had once been called "The Saliferous Marl," and it was owing to the dissolving away of the surfaces of the beds of salt-rock by underground waters, in the manner presently to be described, that the subsidences of the ground had taken place.

There was reason to believe that rock-salt underlies nearly the whole plain of Cheshire formed of the New Red Marl, occupying an area of about 500 square miles. The occurrence of the salt beds had been proved at Northwich, Winsford, Dunham, Anderton, Moulton, Middlewich, Wheelock, Roughwood, Lawton, Baddiley, Dirtwich, Audlem, Nantwich, and Combermere Abbey, all in Cheshire; and Mr. Ormerod had some years ago endeavoured to trace the lines of faulting, or dislocation, traversing the country, according to the different levels at which the beds of salt had been proved. (Quart. Jour. Geol. Soc., Vol. IV.)

It is uncertain, however, whether the salt beds always occur in the same stratigraphical position; and the section of the Marston mine, which the author had visited, showed that there are at least two thick beds of rock-salt at Northwich, having a combined thickness of about 180 feet, and at Winsford of 210 feet.

This section was as follows:—

Section passed through by the shaft of the Marston Mines, Northwich.

	thickness.	
1. Boulder Clay, 2. Red Marl with gypsum,	144	feet.
3. First bed of rock-salt,	75 to 84	,,
4. Indurated marl,	30	,,
5. Second bed of rock-salt,	96	,,
6. Marl and shales with bands of salt,	180	,,

The section had not penetrated further, but the author believed that the New Red Sandstone would be found at a short depth underneath.

Beds of rock-salt have been proved in other districts where the Red Marl formation occurs, as at Droitwich and Stoke in Worcestershire, Shirleywich in Staffordshire, Rugby in Warwickshire, Middlesborough-on-Tees (under the Lias), Southport and Preesal, near Fleetwood.* The rock-salt worked at Carrickfergus, discovered in 1850, in a boring in search of coal, occurs in three beds, one of which is eighty-eight feet thick, and 572 feet from the surface.

At Northwich the pumping of brine, from which the "white salt" is obtained by evaporation, has been in progress for many years. Mr. Dickenson, in an official report made by order of the Government in 1873†, has shown that in consequence of the salt works there are two kinds of subsidences in progress, namely, those due to the falling in of old mines of salt-rock, and those due to the solution of the salt-rock owing to the pumping of brine. The former class are local and restricted, although one of these at

* Mr. J. Dickenson, Trans. Geol. Soc., Manchester, Vol. XVI. Mr. Dickenson says, that Budworth Mere and Pickmere are evidently on the outcrop of the top bed of salt-rock and Rosthern Mere on that of the bottom bed. But on consulting the maps of the Geological Survey, he will see that owing to a large fault marked on the map these three meres occupy the same position with reference to the strata.

† Report on "Salt Districts (Landslips)," by Joseph Dickenson, Inspector of Mines.

Wilton is about 450 yards in circumference, and there are many of 250 yards near Northwich.*

The subsidences due to the latter cause are widely extended. At Wilton Mill, in the valley of the Weaver, above Northwich, a large mere (or lake) is now in course of formation, and has been observed to widen its banks since 1790. In 1857 the water covered an area of about 1,300 yards in length, and 400 in breadth, and since then there have been several fresh depressions.

The two lakes called Budworth mere and Pick mere, north of Northwich, have visibly extended—and as they lie in the same valley—they will doubtless ultimately coalesce. Hollows are also being formed at Birches Hall near Winsford, Billinge-green, between Sandbach and Northwich, and near Martin Hall. In the neighbourhood of Crewe, Winsford, Middlewich and other places, the ground has been undergoing a process of lowering for many years, and these have culminated in the recent disastrous subsidences at Northwich, which have been graphically described in the public press.

At Northwich the depth at which the brine is found is about 132 feet below the canal level,† and it is kept down by continuous pumping nearly to that depth. This is about the depth of the upper bed of rock salt. When just tapped, the brine usually rushes in with force. The earlier attempts at sinking into the strata containing the brine—especially amongst old workings of salt-rock—were exceedingly hazardous‡; recently the tapping of the brine is more safely effected by the aid of iron cylinders, as described by Mr. Dickenson in his interesting Report.

From what has been stated above, it will be clear that the Northwich subsidences are due to the solution of the surface of the upper bed of rock-salt, owing to the constant pumping of brine, from which the salt of commerce is obtained. Some idea of the extent to which this process is carried may be formed when it is known that upwards of one million tons (of twenty-six cwt.) are annually obtained by evaporation of brine in Cheshire

* The term "wich" is an old Saxon name for a salt spring. It is used in the "Dom bôc" or Domesday Book.

† The canal is ninety-six feet above the level of an ordinary spring tide at Runcorn so if all the salt-rock were dissolved away the valley would be submerged deeply.

‡ The processes are described by Mr. Dickenson's Report, p. 22.

alone, while the rock-salt is extracted to a very large extent by mining. In 1879 the quantities produced in Cheshire were as follows:—

Rock-salt, ...	88,853	tons of 26 cwt.
White salt, ...	1,087,214	„ „
	1,177,057	

Of this 1,045,897 tons was sent down the River Weaver from the Northwich district, so that the process of solution and excavation is rapidly going on.*

The process may be briefly described as follows:—

Water from the surface—consisting of a portion of the rainfall and leakage from the River Weaver and other streams—finds its way downwards through the strata of shale, marl, and bands of stone overlying the rock-salt bed, and lodges on the surface, filling old hollows and excavations, and dissolving the solid salt-rock till impregnated to an extent varying from 21 to 25·5 per cent.† There are also salts, and carbonates, varying from 0·6 to 2·5 per cent., and the general analysis shows that the components resemble those contained in sea water. The brine is being pumped as fast as formed; and as the upper surface of the bed of salt is lowered, the ground above necessarily falls with it. In this way the land about Northwich has subsided to the extent of no less than seventy feet within the memory of man; and it is supposed that the top bed of salt is in some places almost entirely dissolved away. The consequence is that roads, canals, railways, and culverts have constantly to be banked up, and are rising higher and higher relatively to houses and other buildings, which subside with the surface, and are often considerably out of the vertical position. Should the process above described proceed till both the beds of rock-salt are consumed, a large tract of country, including the valley of the Weaver, will be submerged beneath the sea.

This brings me briefly to refer to the "meres" or little lakes, which form so peculiar a feature in the landscape of Cheshire. These are distributed over the central plain, and are of various

* Hunt's "Mineral Statistics" for 1879. The total produce of the United Kingdom for the same year was 2,558,368 tons, of which Ireland produced 30,234 tons.

† According to analyses made by Dr. Holland in 1808.

sizes, from Combermere, which is nearly a mile in length, to small ponds, some of which—like that of Crewe Hall—have been artificially extended by embanking. Besides Combermere, there are Rosthernmere, near the northern margin of the Keuper marls, Talton mere—mere lake—Tableymere Pickmere, Rudworthmere, Flaxmere, Oakmere, Oultonmere, Crewe Hall mere, Doddingtonmere, and Ellesmere.* These all (or nearly all) are situated on the New Red Marl formation, which is generally covered by sand, gravel, and boulder clay. No similar group of little lakes is to be found in any part of England beyond the mountainous districts.

As far as I am aware, no full investigation regarding the origin of the Cheshire meres has ever been undertaken. Mr. Ormerod is believed to have originally suggested, that they owe their existence to the melting of the salt-rock. In 1869 I published the following statement:—"There seems to be considerable force in the view, originating, I believe, with Mr. Ormerod, that the meres, or little lakes, of Cheshire may owe their origin to the local subsidence of the ground, consequent on the abstraction of rock-salt, at present or formerly existing under these spots, by dissolving into brine, which is being constantly carried away by drainage at intervals over the whole area of the New Red Marl."† Of the mode in which such lakes may be formed we have evidence in the cases of the subsidences at Northwich, at Martin Hall near Winsford, at Crewe Hall, and at Combermere Abbey. This last instance occurred about the year 1533. Leyland, in his "Itinerary," relates that "part of a hill, with trees upon it, suddenly sank down, and was covered by salt water, of which the Abbot being informed, caused it to be wrought, but the proprietors of the Wiches compounding with him, he left off working." He adds, that this salt pool still continued in his time, but that no care was taken of it.

* Owing to the depth of the Drift over the country about Ellesmere, there is some uncertainty regarding the formation underlying.

† "The Triassic and Permian Rocks of the Central Counties." Mem. Geol. Survey, p. 101. In Mr. Ormerod's valuable paper on the "Salt Field of Cheshire." Quart. Jour. Geol Soc., Vol. IV., in which he traces the range of the salt beds and the faults by which they are dislocated. The view above stated of the origin of the meres is rather to be inferred than stated.

The process of dissolution of the salt beds by a natural process of filtration, underground flow of waters impregnated with salt, and their discharge in the form of springs, has been going on for a lengthened period, extending back into pre-human times. Such springs are still flowing in some places, notwithstanding the large quantity of brine artifically extracted from the ground by pumping. The flow of the brine springs must have materially affected the relative surface levels, and where, from some cause or another, the dissolution has gone on more rapidly than in the surrounding district, the subsidences would be more rapid, and a hollow would be formed, into which the surface waters would flow and form a lake or mere. In this manner it is probable all these peculiar sheets of water, generally lying in deep hollows, and known as "the Cheshire meres," have been formed; and when once formed, the tendency would be for them to become larger as time went on.

It may therefore be affirmed that the origin of the Cheshire meres and the Northwich subsidences is similar, only that in the one case the process has been a natural one, in the other artificial.

XV.—On the Identification of Certain Localities Mentioned in My Paper on the Diamonds of India, by V. Ball, M.A., F.G.S.

[Read, February 21st, 1881.]

Since my return to India I have been enabled by having access to several books and maps to fix the position of some of the oldest diamond mines whose identification has been a puzzle to previous writers. I shall not give all the details here, but since this Society was the medium by which my paper (*vide* these Proceedings, Vol. II., N.S., p. 551), was published, I think it right that I should hasten to make what *amende* I can for having given currency, on the authority of other writers, to views which I am now compelled to withdraw.

Raolconda.

This locality has been a great puzzle to most writers in consequence of their trying to identify it by means of Tavernier's statement that it was five days journey from Golconda, and eight or nine from Visapour (the modern Bijapour). Elsewhere, however, he gives a list of the stages—nine in all—between it and Golconda, the sum of the distances being, I compute, equal to 189 miles. I am, therefore, compelled to believe that in Tavernier's first statement the days' journeys were transposed, and that it should be read eight or nine from Golconda, and five from Visapour. With these new indices of position we at once find a town on the map bearing the name Rawduconda, in Lat. 15° 41′, and Long. 76° 50′.

Unfortunately the geology of this locality is not at present known, but metamorphic rocks have been observed to occur at no great distances both to the north and south of it. It is possible that there may be an outlier of the Karnul rocks there. I have not yet succeeded in finding any recent account of diamonds being known to occur there.

Gani or Coulour.

This locality, regarding which I have given a quotation from Tavernier, was almost certainly identical with Purtial, in Lat. 16° 39′, Long. 80° 27′, although Capt. Burton located it on the Bhima river. According to Tavernier, whose stages can to

some extent be identified, it was seven days' journey (about 150 miles) east of Golconda.

At it was found the famous Great Moghul diamond, which by some is considered to have been the Koh-i-noor; it then weighed 900 carats.

Soumelpour, not identical with Sambalpur, on the Mahanadi.

The Soumelpour of Tavernier on the Gouel river, has been identified by most writers (Karl Ritter being perhaps the only exception), with the modern Sambalpur, and I regret to say that when writing my paper I did not give Tavernier sufficient credit for geographical knowledge, and in spite of his saying that the washings were in the Gouel river which flowed northwards to the Ganges, I followed suit in locating Soumelpour on the Mahanadi river.

There can be no doubt, however, that the Gouel river was the Koel, and that Soumelpour was situated in the district of Palamow somewhere, not very far from Lat. 23° 53′ 30″, Long. 84° 33′.

Beiragurh identical with Weiragurh.

I mentioned in my paper a locality—Beiragurh—as having been alluded to by early historians as the site of a diamond mine, and I quoted several suggestions as to its identity. I now find that it is the same place as the modern Weiragurh in Lat. 20° 26′, Long. 79° 31′ 30″, and which I have described in my paper on page 576.

I hope to publish the details of the above identifications in the Journal of the Asiatic Society of Bengal, where they will have the advantage of local criticism. The above sketch of the results will probably be deemed sufficient as a correction of and addition to my former paper read before this Society.

Calcutta, 8th Dec., 1880.

XVI.—CONCLUDING NOTE ON THE MANUFACTURE OF PAPER FROM MOLINIA CŒRULEA, BY W. SMITH, C.E.

[Read, March 21st, 1881.]

In November last, I brought under the notice of this Society a new raw material suited for the manufacture of paper, commonly known as Melic grass. I then mentioned that two trials were being carried out; both have been completed. One—that made in Scotland has not been a success, as unfortunately, as sometimes happens when treating new materials on a working scale, too much or too little of whatever chemicals have to be employed is used. In this case, I believe, too much caustic soda was used in treating the grass; and still more unfortunately, all the supply was used up in one trial, thus preventing the possibility of correcting any mistake. The second trial, made in Dublin, has been, I may say, a perfect success, and confirms the former favourable opinion of this new raw material. The preparation of Melic grass for the purpose of being made into paper is similar to that of Esparto. Both should be carefully picked, to free them from foreign substances, such as twigs, leaves, &c.; they are then boiled in a solution of caustic soda, for the purpose of removing the silica, resin, oils, and facilitating the separation of the fibre; and if white paper is to be made the material having been washed, is bleached.

Mr. Richardson, to whom the merit of discovering the useful nature of this grass is due, has had several analysis made. Nos. 1 and 2 by Dr. Cameron, and Nos. 3 to 8 by the late Mr. W. Arnott, of Edinburgh, well known as an expert in the chemistry of paper-making.

Analysis No. 1.

Water,	23·17
Fats,	3·07
Albuminous substances,	8·00
Non-Nitrogenous extractive matters,	31·17
Woody fibre,	33·77
Mineral matter (ash),	0·82
	100·00

Silica in ash, 0·55.

Per centage of fibre calculated to dry grass, 43·91.

Analysis No. 2.

Water,	13·60
Albuminous substances,	5·90
Oils,	2·03
Soluble non-Nitrogenous matter,	47·77
Woody fibre,	26·00
Ash,	2·20

Analyses Nos. 3 to 8.

	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.
Oils and Resins,	6·26	5·28	10·66	5·68	4·32	3·84
Gums,	3·07	2·92	4·28	3·84	2·25	1·91
Albuminous and other organic substances not soluble in alcohol, ether, or water	27·20	29·65	51·01	34·26	22·82	26·73
Cellulose (fibre),	39·43	37·76	17·89	39·09	62·84	47·06
Mineral (ash),	2·46	1·13	2·48	2·47	1·52	1·42
Moisture,	21·58	23·26	13·68	14·66	6·24	19·04
	100·00	100·00	100·00	100·00	100·00	100·00
Silica in ash,	·17	·03	·18	·16	·62	·08
Bleached fibre, per cent.	39·10	37·44	16·55	38·43	—	45·87
Per centage of fibre calculated to dry grass.	50·18	49·20	20·72	45·80	67·03	57·41

In his report accompanying the analyses (Nos. 3, 4, 5, and 6, were made in December last, and Nos. 7 and 8 in January and February last), Mr. Arnott wrote as follows, viz.: "Sample No. 3, was seed stems grown on rocky clay soil; No. 4, was seed stems grown on bog or peat; No. 5 was leaves grown on bog; No. 6 was a fair average of several bales of both stems and leaves, received for large scale experiment." From these figures it is manifest, 1st, that there is but little practical difference in the amount of fibre contained in the clay and peat-grown samples, not more than I would expect to find between any two samples grown on the same soil. 2nd, The mineral matter, as was to be expected, is more than double in the clay-grown sample as compared with that grown on bog land; but the per centage is not great in either case, and the silica, although six times greater in No. 3 than in No. 4, is still so low as really not to entitle it to rank as a matter of importance. The leaves, No. 5, as is natural, contain much less woody fibre than the stems.

The fibre set down in the analyses is that portion of the cellulose available for paper making, and as I have made my analyses from a paper making point of view, I have been careful to report only such cellulose as has been indurated, and capable of being

utilized by the paper maker. The average sample, No. 6, was much drier than No. 3, to begin with, and has given, in my opinion, a very satisfactory result.

So far as I have been able to judge from the laboratory experiment, the grass promises well; much better, indeed, than my first acquaintance with it in the raw state led me to expect.

It improves by boiling both in strength and flexibility; is easily boiled with from 10 to 12 lb. 60 per cent. caustic soda per cwt., and bleaches to a good colour with very little loss in the process, with a comparatively small per centage of bleaching powder. Samples No. 7 and 8.—The analytical results speak for themselves. No. 7 contains a much larger amount of fibre, and a stronger fibre than No. 8. The ash is not at all excessive; the moisture is at a minimum, but the silica present is considerable, and judging from the small scale experiments this grass would take about 14 lbs. 60 per cent. caustic soda per cwt. to boil, and I am confident it would bleach readily with a small quantity of chloride of lime. It forms a strong flexible fibre. No. 8 contains generally speaking only one-half of the quantities of gum, resin, &c., that the former sample had, while it has a much lower ash and silica.

Notwithstanding the hand drying before the fire, and the apparent dryness of the grass to the touch, there is a large amount of moisture present, about double that usually found in Esparto. The fibre is considerably higher than in any previous sample, while the chlorophyll or green colouring matter is almost absent. The fibre is easily bleached, and is a much better sample in every way than the best of those reported on in December, 1880.

Sample No. 7 referred to by Mr. Arnott is what, perhaps, might be named Giant Melic Grass; it was grown in the Trinity College Botanical Gardens, and No. 8 was grown at Tyaquin, but collected in January last. The analysis of No. 7 indicates that by selection it will be possible to improve the fibre-producing quality of the grass, and both Nos. 7 and 8 show that the proper time to harvest the grass is in late autumn or early winter, as by waiting until then not only is the fibre increased in quantity, but the chlorophyll which causes trouble in bleaching is nearly eliminated.

There is now no question as to the value of the grass as a paper making material, and the only question to be solved is as

to the supply, which will mainly depend on the facility of growing it on waste or bog lands. As before mentioned, the grass grows freely on even only partially drained bog. Last year trials were made to grow the grass from seed in prepared bog land; but owing to the seed being bad, the experiment failed. And this seed had been imported from Germany and France, but it has since been found that all the seed of the year 1879 was bad. Last year Mr. Richardson collected seed in Galway and also had samples from Germany and France. Doctor M'Nab has kindly tested the different samples and found the Irish seed to be far the best, being free from weeds and ergot, and germinating well; whilst the foreign seeds are much ergotised, and with one exception, not germinating well. It therefore seems as if the home-grown seed were best, and as the proper time for harvesting the grass is late autumn, it will be practicable to collect the seed from the standing crop. So far as my observation and enquiries enable me to form an opinion, the best preparation for growing the grass is burning the surface of the bog. There is at present a large and increasing demand for a raw material, such as Melic grass, and perhaps it might be considered worthy the consideration of the Agricultural Committee of the Royal Dublin Society whether the growth of this grass might not form a subject for encouragement on the part of the Society.

Comparing analysis No. 2 of Dr. Cameron, with the other analyses, it will be found to correspond pretty nearly with No. 5 of Mr. Arnott's, and both point to the fact that the leaf part of the Melic grass ought to have a fair feeding value. It would, therefore seem as if it might be possible in some cases to feed off the leaf part of the crop in spring, as is done with rye, and afterwards allow the seed stems, which are of more value for fibre, to mature.

In growing the grass it would be desirable to do so as a crop alone, and thus save the cost and trouble of picking.

In conclusion, I would repeat that in Melic grass we have a raw material, which if grown in sufficient quantity would be gladly purchased by paper makers, and a crop which can be grown on waste lands where no other crop of any value can so far as is at present known be cultivated; and that for the purpose some 400,000 acres of useless wet bog could be utilized at a comparatively small outlay.

XVII.—ON THE ORIGIN AND PROBABLE STRUCTURE OF THE DOMITE MOUNTAINS OF CENTRAL FRANCE, BY EDWARD HULL, B.A.

[Read, April 11th, 1881.]

LAST summer, in company with my father Dr. Hull, and Dr. R. Ball, I had the pleasure of examining that remarkable volcanic region which occupies the province of Auvergne, in central France. With Scrope's exhaustive manual in our hands, and aided by his exceedingly accurate maps and faithful descriptions, we had little difficulty in deciphering the physical geography of this somewhat complicated region.

Our explorations, however, were confined to the district of the Puy de Dôme, as our time did not permit us to extend our rambles so far south as the Mont Dore district or into Cantal. This region is composed of a central group of volcanic cones and craters, extending long fingers or "cheires," as they are locally named, of lava out into the plain of fresh-water formations, limestones, marls, and alluvial deposits, which form the basin of the Allier river, one of the principle tributaries of the Loire. This region of volcanoes may be divided roughly into two groups: 1, the *Domite* division, composed of a trachytic form of lava, and pre-eminent alike by their mineralogical character, size, and shape; and 2, the *surrounding volcanic* hills, composed of scoriæ, ashes, and debris, all truncated cones, their sides sloping at the invariable angle of 30°, and nearly always with one side broken down and emitting a stream of basalt, which flows for a variable distance over the surrounding country.

It is extremely probable that, in accordance with a very usual law, these two groups are also divided *chronologically;* the Trachytic or Domite hills being of older formation than the basaltic vents, otherwise it is hard to explain the isolation of the former, their bases swept by flows of basaltic lava from the throats of the surrounding craters, and standing completely isolated in shape as in mineralogical character from their nearest neighbours.

I do not intend to go into the question of the origin of

Domite; this must at any rate be left to *mineralogists*, and even if I were capable of discussing the subject, I should be sorry in any way to deprive them of such an interesting bone of contention; but all I shall attempt to do is to advance what I hope will be considered a reasonable theory of the internal structure and mode of origin of these strange elevations.

Just to mention the older theories—Desmarest considered them to have been originally composed of granite, which was afterwards calcined *in situ* by a volcanic conflagration environing it! This hypothesis requiring, I conceive, for its elaboration the vivid but superficial imagination of a Frenchman. Others, Von Buch and Humboldt included, thought that they were enormous *bubbles* blown up by subterranean gases and solidifying in that shape—a theory one would suppose considerably more hollow and unstable than it would fain have made the mountains themselves.

Scrope draws attention to the probable viscosity of the mass of Domite when in a molten state, in contradistinction to the comparative fluidity of basaltic lavas; but does not explain, I think, how this viscosity was able to raise mountains some 2,000 or 3,000 feet above the level of the surrounding plain. I proceed to lay before you the following considerations on the subject.

This Trachyte or Domite being composed almost exclusively of felspar, with crystals of augite and mica in small proportion, has a comparatively low specific gravity, which is again much lessened by its very granular and porous character and the contained bubbles of air, so that its specific gravity is as low as 2·50, or even lower; but this will be sufficient for my purpose.* When we come to examine the basalt of which the more recent lava-flows are composed, we find *its* specific gravity to be much greater, namely—3·0 to 3·10. I will take the average figure or 3·0.

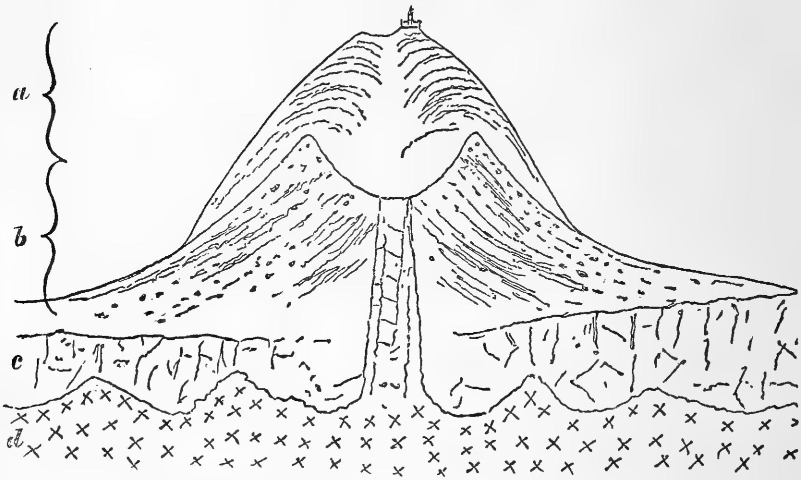
* Since writing the above I have taken the actual density of a piece of Domite, and its specific gravity is exactly 2·5. This, however, is after it had been thoroughly soaked in water, and all the air which lodges in its pores expelled. How large a quantity of air is contained in this rock may be judged from the fact that on putting this piece into water it appeared to effervesce, the air escaping in such abundance. Scrope states that when a shower of rain falls on these Domite hills a loud hissing noise is produced, which I can well believe, although we were not so fortunate as to witness the phenomenon. This all points to its density while in the molten state, having been very much less than this; but, as I said, this actual density is sufficient for my purpose.

Now, it will generally be conceded, I imagine, that every volcano which aspires to rise to any height above the surrounding level will, as a preliminary measure, throw up a cone of ashes and scoriæ, and this we find to be actually the case both in modern eruptions, and in these extinct but well-preserved craters which form the bulk of the Auvergne range. When these craters are formed the next thing that happens is that the lava will begin to rise up in them, and it would continue to do so till it filled them to the top, if it were not that the lateral pressure of a fluid mass of such high specific gravity becomes too great for walls of such loosely aggregated material to sustain, so that almost invariably one side gives way, and the lava bursting through deluges the surrounding plain. Now, in some of these cones we have a means of estimating the exact height to which the lava rose before the side of the cone prolapsed, for, according to Scrope, in the crater of the Puy de la Vache this lava level is still marked by a projecting ridge of light scoriaceous matter of a reddish yellow colour, rich in specular iron, apparently part of the frothy scum which formed upon the surface of the ebullient lava, and adhered to the side of the vase at the moment of its being emptied. We verified his observation as far as this ridge of slag is concerned, and it certainly had all the appearance of having been formed in the way he suggests.

Now, this line is about 30 or 40 feet below the present ridge of the crater, and allowing twice this amount for denudation we may safely say that the lava rose to within 90 or 100 feet of the edge of the crater before it burst its way through. But it must be remembered that the density of these basaltic lavas was very high, *i.e.* 3·0 or 3·1. If we suppose them to be replaced by a lava like the *Domite*, having so much lower a specific gravity, it will be readily seen that in that case the lava might completely fill the crater before it began to overflow, which it would then do regularly and evenly at every point of the circumference, without any tendency to break down one of the sides of the crater. This viscous semi-solid mass, permeated with gas bubbles, and with a strong tendency to solidification, would then creep slowly down the sides, forming those inverted bowl-shaped mountains which are so peculiar and distinct in form from the ordinary craters.

The annexed diagram is a section of the Puy de Dôme, constructed in accordance with this idea, and it certainly appears to me that the hypothesis is strengthened by the fact, that the mountain rests upon a base of ashes and scoriæ through which the road winds before one commences to make the ascent of the steepest part of the hill, which commences very abruptly.

Section through Puy de Dome.



a. Cap of Domite.
b. Cone of ashes and scoriæ.
c. Much older basalt from Mont Dore district.
d. Granite forming fundamental plateau.

It is quite easy on simple hydrostatical principles, and with the aid of the data which I have given, to verify at any rate the *possibility* of this explanation, and thus to entitle it to hold its own until a more feasible one is proposed, or this shall have been put to the test of experiment. It is a mere question of the difference in hydrostatic pressure between a column of molten lava of a specific gravity of 3·0, and that of one of the same height, but having a density of only 2·5. Now, in one of these cones the bursting pressure was attained when the heavier lava rose to a height of 800 feet in the crater, and was represented by a pressure at the base of the column of 80 atmospheres or 1,200 lbs. on the square inch. (I presume these cones gave way somewhere near the base,

but to calculate the height at which such a cone would *have* to give way would involve more mathematics than I am master of, and it has no immediate bearing on my subject.) If we suppose this same cone to have been filled with the lighter lava, or Domite, the pressure of a column of this lava of the same height would only have been some sixty-six atmospheres, or 1,000 lbs. on the inch square, against 1,200; or in other words, it would have taken a column of the Domite lava 960 feet in height to produce a pressure equal to a column of the Basaltic lava 800 feet high.

So that as a *matter of fact* this Domite lava, supposing it to have been discharged from a crater of a conical form, as from all analogy we have strong reasons for thinking it must have been, could have acted in no other way than that which I have endeavoured to describe, and would thus have produced bowl-shaped masses of the appearance presented in Auvergne.

XVIII.—PHOTOGRAPHIC SPECTRUM OF COMET, BY WILLIAM HUGGINS, D.C.L., F.R.S., &c.

[Received, June 28th, 1881.]

On Friday night (24th June,) I obtained, with one hour's exposure, a photograph on a gelatine plate of the more refrangible part of the spectrum of the Comet which is now visible. This photograph shows a pair of bright lines a little way beyond H in the ultra-violet region, approximate wave length, 3870–3890, which appear to belong to the spectrum of carbon (in some form), which I observed in the visible region of the spectra of telescopic comets in 1866 and 1868. There is also in the photograph a continuous spectrum in which the Fraunhofer lines can be seen. These show that this part of the Comet's light was reflected solar light. This photographic evidence supports the results I obtained in 1868, which show that comets shine partly by reflected light, and partly by their own light, the spectrum of which indicates the presence in the Comet of carbon, possibly in combination with hydrogen.

PUBLICATIONS OF THE ROYAL DUBLIN SOCIETY.

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Part 10.—On the Possibility of Originating Wave Disturbances in the Ether by means of Electric Forces. By G. F. FITZGERALD, M.A., F.T.C.D. (February, 1880.)

Part 11.—On the Relations of the Carboniferous, Devonian, and Upper Silurian Rocks of the South of Ireland to those of North Devon. By EDWARD HULL, M.A., LL.D., F.R.S., Director of the Geological Survey of Ireland, and Professor of Geology, Royal College of Science, Dublin. With Plates IV. and V., and Woodcuts. (May, 1880.)

Part 12.—Physical Observations of Mars, 1879–80. By C. E. BURTON, B.A., M.R.I.A., F.R.A.S. With Plates VI., VII., and VIII. (June, 1880.)

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Part 7.—Pages 551 to 634. With Title. (November, 1880.)

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Part 1.—Pages 1 to 32. (January, 1881.)

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Part 3.—Pages 61 to 150. (July, 1881.)

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The Evening Scientific Meetings of the Society and of the associated bodies (the Royal Geological Society of Ireland and the Dublin Scientific Club) are held in Leinster House on the third Monday in each month during the Session. The hour of meeting is 8 o'clock, P.M. The business is conducted in the undermentioned sections.

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XIX.—NOTES ON THE TERTIARY IRON ORE MEASURES, GLENARIFF VALLEY, COUNTY ANTRIM, BY PHILIP ARGALL. PLATES 16, 17, 18, and 19.

[Read, April 11th, 1881.]

HAVING been for some time engaged at the Iron Mines of Glenariff, and having paid some attention to the Iron Ore Measures and associated strata, perhaps I may be allowed to lay before the Society some of the notes I have made from time to time, more especially as I am led to believe that the true nature of the iron ore deposits have still to be learned.

As an introduction, it may be allowable to give a short description of the valley and its rocks. Glenariff is the south-west land continuation of Red Bay, probably so called from the Red Sandstone cliffs which form its northern shore.

The glen is perhaps the most beautiful of all those indenting the Co. Antrim. Around the basaltic tipped chalk cliffs rise to heights, in places, of 800 feet, their continuity and colours being broken and diversified by deep ravines, faults, and landslips, and over them in places streams of water fall, forming picturesque cascades, often perpendicular, of from 50 to 300 feet in height; while in the distance, as a back ground, across the North Channel, is the Mull of Kantire, with its lighthouse, and the Highlands of Scotland.

At its junction with Red Bay the Glenariff Valley is a mile wide, the red Triassic rocks forming the base of the sloping undercliffs, on either side, but these rocks are best seen at the north or Waterfoot side, where they rise to a height of nearly 200 feet. A quarry was opened in these rocks to procure stone for Red Bay pier; the rocks being traversed by an interesting dolerite dyke which throws up numerous shoots and branches as represented on Plate XVI. The main dyke bears N. and S.* and dips 85° to the west. The largest shoot bears also N. and S. but dips east at 75°, and would probably unite or drop into the large one at a moderate depth; these dykes at low water can be traced for some distance along the shore, standing up in a wall

* This and other bearings are magnetic.

about four feet above the Trias. The sandstone near the dyke and branches, is much altered and baked, the original structure of the rock being entirely obliterated.

To the N.E., near Cushendall, the Trias rests direct on a massive conglomerate, which is principally made up of granite and quartz fragments (Lower Old Red Sandstone or Silurian). Thus no coal measures occur in this section, nor is it probable they would be found by boring in Glenariff, if the opinion expressed by your late President (Mr. Kinahan), is correct; namely, that this conglomerate is one of the "shore beds" of the Silurian rocks, that further south-west occur in mass in Tyrone and Fermanagh, still it is not improbable that coal measures may exist further southward under the Tertiary and Secondary rocks at Carnlough or Glenarm.

Over the Trias there are thin bands of greensand, principally yellow and greenish sandstones and brownish clays, with more or less calcareous bands. In the upper beds, calcite veins are frequent, and in one place asbestos occurs in the joints close to a considerable fault, which throws down the basalt nearly against the greensand. At the base of the cretaceous rocks is a very thin bed of fine conglomerate made up of rounded pieces of quartz, and fragments of chlorite in a sandy calcareous matrix. The inlying fragments vary in size from that of a pea to that of a hen's egg, and are usually so fixed in the matrix as to break with it. This seems to be the representation of the upper bed of the "Hibernian greensand" of Tate, and from its appearance it is locally called "concrete."

The Lias, which is of considerable thickness near Larne, does not seem to occur in Glenariff, though there is a small exposure of it a little to the east of Garron point.

The overlying white limestone (indurated chalk) has a specific gravity of 2·6, with a semi hackly fracture; the numerous contained flints sometimes occur in layers parallel to the bedding, but are often scattered irregularly through the mass; the bedding planes are seldom well developed but when they are, the rock quarries into large and good building stone. The most conspicuous and numerous fossil is a bellemnite, scarcely a large stone can be quarried that does not contain one or more, while they are also frequent in the flint nodules. The purity of the

chalk and its whiteness facilitates its manufacture into whiting and bleaching powder; when burnt it becomes an excellent lime for agricultural purposes.

In places on the white limestone forming the basal bed of the Tertiary, is a thin ferruginous conglomerate made up principally of abraded flints, clay, and gravel; but occasionally we find a stiff brownish clay (which much resembles the pavement hereafter mentioned, page 156), having imbedded pieces of burnt-looking flint and limestone, also occasional pisolites of iron ore; sometimes, however, the dolorite rests direct on the chalk.

The other rocks of the Tertiaries are the dolerites, basalts, and Tuffs; under the latter being included the laterites, iron ore measures, bauxite (silicate of alumina), and such like. The dolerites may be divided into *upper* and *lower*, or those above and below the main iron ore measures.

The dolerites and basalts occur in flows, protrusions, and dykes, while associated with them are partings of laterite, the ferruginous beds of lithomarge, aluminous and pisolitic iron ores, and seams of lignite. The dolerites are more or less crystalline, sometimes being porphyries, having in them well developed crystals of labridorite and augite, occasionally they exhibit columnar and amygdaloidal structures and have peculiar concretionary weathering; both they and the basalts when in bedded masses occupy large areas, while the tuffs are of more or less limited extent.

The flows of dolerite vary from a few feet to thirty or forty in thickness; usually between them are ferruginous accumulations, to which I drew the attention of Mr. Mallet, of the Indian Survey, during a visit to the mine last summer, and he expressed an opinion that the compact varieties were somewhat similar to the laterites that in India occupy large areas, are often 200 feet deep, and contain nodular iron beds twenty to forty feet thick. Here, however, the beds or partings are only from a few inches to about seventy feet, while in general they do not exceed two feet thick. In places these thin laterites graduate into good aluminous iron ore, but in no case have I found the latter assuming the pisolitic structure; although in the iron ore measures similar aluminous ores will occasionally have pisolites scattered through them when immediately under the pisolitic ore.

The laterites between the dolerite flows are generally of a red, or reddish brown, colour and very tough; it is invariably amygdaloidal, the cells containing zeolites and aragonite. The laterite partings between the lower beds of dolerite are usually softer or more decomposed than those between the upper beds, and very often graduate into thick ochre and bole beds; this is not so common in the upper dolerites, but in every case which has come under my notice the iron ore measures alone excepted, the laterites are very vesicular and contain large quantities of zeolites. I have also frequently observed manganese oxide in the cells.

From the papers and memoirs on the laterites and associated iron ores to which I have had access, it would appear that they are supposed to be accumulations due to the disintegration of trappean rocks during periods of successive volcanic outbursts; for such a theory I do not, however, see sufficient evidence. The thin ferruginous beds of bole between most of the large flows may doubtless be formed from the disintegration of the scoria or surface of the flows; but the materials forming the thick beds such as the iron ore measures, could scarcely have had such an origin. Their thickness, structure, and other characters suggest that possibly they are eruptions of ferruginous mud, ejected at intervals between the basaltic flows by volcanic agencies, or perhaps eruptions of ferruginous dolerites and tuffs which subsequently decomposed *in situ*. The beds of aluminous ore seem to be contemporaneous with the accumulation of the associated beds, and in all probability are a sedimentary deposit, but the pisolitic ores have characters which would appear to refer their origin to some other cause.

The iron ore measures of Antrim vary from ten to seventy feet in thickness; in the Glenariff mines they do not exceed sixty feet; they and the associated rocks give the following section:—

	Feet.
Upper Dolerites, ...	300
Iron Ore Measures, ...	60
Lower Dolerites, ...	250
Basal Conglomerate, ...	2
White Limestone, ...	70
Feet, .	682

The iron ore measures give as a typical section :—

				Ft.	In.
6.	Steatitic Rock,	local name	"Brushing,"	0	8
5.	Steatitic Clay,	,,	Holing, . 1 inch to	0	3
4.	Pisolitic Ore,	,,	First Ore,	1	7
3.	Aluminous Ore,	,,	Second Ore,	2	6
2.	Ochreous rock,	,,	Pavement,	15	0
1.	Lithomarge,	,,	Marge,	40	0
			Feet,	60	0

The floor of the lithomarge usually is an irregular surface of dolerite, which in places is corroded into deep holes; dolerite is also found in decomposing masses and boulders in the bottom beds of the lithomarge (see Plate XVII.) In some places the decomposed dolerite passes insensibly into the lithomarge, but in general it is darker than the surrounding lithomarge, and being vesicular, presents a marked contrast to it. The bottom beds of the lithomarge are generally of a light lavender colour containing numerous white spots of bauxite, which vary in size from a pin head to that of a pea; the upper beds are brown or blackish. It is a brittle and splinty rock, and flies from the pick like flint, but is never hard enough to resist being easily cut with a knife, occasionally it is altered by a dyke into an extremely tough rock. When exposed to the weather it becomes soft and breaks into cubes, which eventually weather into spheroidal forms. Interstratified with the lithomarge are inliers of aluminous iron ore, usually as beds varying from a few inches to several feet in thickness, but often only as lenticular masses. Sometimes small partings of a silicious lignite are found in this aluminous ore, also lumps and thin seams of lignite, but I have never observed lignite in the associated lithomarge, though it often occurs in the pisolitic ore seam, as will be described hereafter.

There are interesting circumstances in connexion with the lithomarge when it comes in contact with peat water, which may be here mentioned. When peat water passes over an exposure of lithomarge, oxide of manganese frequently accumulates in the cavities and interstices, one irregular fissure was filled with pyrolusite (of 70 per cent. Mn. O.) in places three inches thick, but on an average not more than one inch in depth, the walls came together, and cut out the seam. The manganese would appear to be in solution in the peaty water, and to be deposited by some pro-

perty in the lithomarge. Also the peat water seems to have a solvent action on the dolerite, from whence it probably draws its supply of manganese and iron, as stones taken from the bogs have white envelopes of $\frac{1}{8}$ to $\frac{1}{4}$ inch in depth, in which there is scarcely a trace of iron, while below this crust the dolerite is dark and very little altered. It may also be mentioned that in the mountain bogs lumps of cellular iron ore are found with the cells filled with oxide of manganese. If these solvent and precipitating actions are at all general, which they ought to be, deposits of manganese should be going on in various places in connexion with the trap area.*

The Ochreous rock over the lithomarge is called "pavement" by the miners, as it forms the floor or pavement of the iron ores. In it the levels and tunnels for extracting the ore are usually driven; it is a soft rock and can easily be cut with the pick. The pavement seldom contains bauxite, except where it is traversed by a dyke, near which the spots are large and numerous.

In general on the pavement, the aluminous or second ore occurs, in the upper portions of which are scattered pisolites (peas of the miners) of iron, and resting on this is the "first" or "pisolitic" ore. In the latter the pisolitic structure is always best developed at the top of the bed, it also being the richest portion, containing larger and more numerous pisolites than lower down.

The pisolitic ore varies from twelve to twenty inches in thickness, but occasionally reaches twenty-four or even thirty inches. In colour it varies from red through brown to black, some of the latter coloured pisolites shine like graphite; the red ores always are over the others; generally, however, the seam of pisolitic ore is of one colour throughout its thickness, this in the Glenariff district is usually dark brown or black. It is the matrix or cementing material for the most part that gives the colour to the ore, the pisolites are generally black, though in red ores they sometimes take a red colour, but of a darker shade.

Near the "face" or cliff outcrop of the seam the ores are soft, the pisolites being in a friable mass of peroxide of iron, but as the bed is followed in, it becomes harder and the pisolites are cemented firmly in the matrix; while at twenty to thirty fathoms from the outcrop the ores are usually too hard for pick working

* See Notes added in the Press. No. 2.

and have to be shot or wedged out. The ores also get harder as the roof or perpendicular weight increases; thus under high escarpments good firm ore is found at five or six fathoms from the outcrop. These are important facts, because at present the best ores may be deteriorated by their fineness, which would prevent them being used by themselves in the blast furnace. As the ore from the shallow workings are exhausted and the mines extended into the heart of the mountain, the ore ought to get harder and contain a greater percentage of lumps, thereby enabling it to compete more favourably with the Spanish ores.

In the present workings the matrix is seldom hard enough to hold the pisolites in position and allow them to be broken across they coming out during the breaking of the ore; but if the beds are traversed by a dyke (which penetrates the roof) the adjoining portions are baked into a compact mass, and under these circumstances the pisolites break with the matrix. The pisolites vary in size from a shot to that of a hazel nut, while the quality and richness of the ore can be estimated with great accuracy, by observing the size, quantity, and hardness of the pisolites. The pisolitic ore contains from 40 to 70 per cent. of iron, the following being analysis of average samples of Glenariff ore :—

—	Pisolitic Red Ore.	Pisolitic Black Ore, Magnetic	Pisolitic Black Ore, Magnetic.	Aluminous Ore.	Aluminous Ore.	Pavement.	Pavement.
Iron Peroxide,	62·43	71·64	67·54	28·83	35·93	28·44	27·96
„ Protoxide,	4·75	1·88	trace	2·50	trace	trace	trace
Manganese Protoxide,	0·28	0·27	0·17	trace	0·11	trace	0·18
Alumina,	10·19	4·25	1·75	34·70	36·50	38·14	4·40
Lime,	2·80	0·81	Nil.	Nil.	0·53	Nil.	trace
Magnesia,	0·59	0·61	trace	1·51	1·41	1·10	trace
Silica,	8·40	5·05	10·93	15·40	12·20	15·90	38·70
Sulphur,	Nil.	Nil.	Nil.	trace	Nil.	trace	Nil.
Phosphoric Acid,	Nil.	0·20	Nil.	0·04	Nil.	0·08	0·07
Carbonic „	trace	trace	Nil.	Nil.	Nil.	trace	Nil.
Titanic „	—	8·89	10·80	Nil.	Nil.	trace	6·60
Combined Water,	1·88	—	2·26	9·00	10·23	12·25	11·36
Moisture at 100° C.,	8·48	6·40	5·61	7·80	2·76	4·60	14·78
Loss,	·20	—	0·94	0·22	0·33	—	0·95
	*100·00	†100·00	‡100·00	§100·00	§100·00	§100·43	§100·00

* A. B. Cowen. † Public Analyst, Wolverhampton.
‡ E. W. T. Jones, F.C.S., Wolverhampton.
§ Ditto, ditto.

The thickness of the pisolitic ore seam is by no means regular, a seam of twelve inches may suddenly thicken to twenty-four or

thirty inches due to a cavity or "rise" in the roof (a roll or "gurry" of the miners); also an irregular wavy or undulating structure in the roof may thin and thicken the seam alternately. Small cavities or rugs in the roof are usually filled or lined with beautiful crystals of aragonite, sometimes stained red but usually colourless.

A steatitic clay, like No. 5 in the general section (page 155), is sometimes found separating two beds of pisolitic ore, the upper bed being usually of a red colour; but I have only found this in disturbed areas. Very often the pisolitic ore is found resting unconformably on the pavement, the bole and pavement having evidently been worn away in places before the ore was deposited (see Plate XVIII.); also it is not uncommon to find angular and rounded pieces of aluminous ore and pavement in the pisolitic ore seam, thus giving it a brecciated appearance. In approaching a place where the pisolitic structure of the ore is not well developed and where the ore appears to be indurated by some cause, we usually find a great display of acicular crystals of aragonite on the roof with veins and partings in the ore, which sometimes cement it to the roof; hence a display of crystals on the roof is regarded by some as a sign of poverty; similarly as a display of spar crystals in a standing vein indicates poverty of mineral matter in the percolating fluids when the vein was being filled.

Sometimes the pisolitic ore is absent and the second ore rises to the roof; at other times both the ores, thus causing the pavement and the roof to join together; this cutting out of the ores is generally caused by the roof dipping down on the pavement. (Plate XVIII.)

The pisolitic ores are more or less magnetic, some being magnatite. In regard to their colours, the red are only slightly or not at all magnetic; while the brown are also, they may graduate into a black true magnatite; the latter contains 8 to 15 per cent. titanic acid, and is very rich in iron. I have frequently found the pisolites of magnetic ore to be polaric, their elongated axis or poles being horizontal in the seam, and apparently conformable with the present magnetic meridian.

Lignite and bauxite are found to occur in connexion with the iron ore measures in various parts of the county Antrim, and

usually replace the pisolitic ore seam, though in places the lignite overlaps the iron ore, in which case the lignite is always separated from the ore by a band of bauxite or aluminous clay. A good lignite bed is, however, seldom found in immediate connexion with the pisolitic ore seam, though it sometimes is separated by a dyke only.

To Mr. P. Gormon, who has bored through most of the lignite and ore deposits of the county Antrim, I am indebted for the following information. In all cases that have come under his observation the lignite aluminous clay and ore deposits are found adjoining each other; often they are separated by dykes, but when these are absent, the clay and lignite usually overlap the iron ore at the junction of the deposits.

At Killymurish, where there was an extensive deposit of lignite, he bored through forty feet of clay under the lignite seam, and on putting down another bore a little to the south of this, on the confines of the Duneny iron ore field, he cut through eighteen inches of pisolitic ore so close to the dyke of separation that the pavement of the ore was wanting. In another portion of this clay field he bored through five feet of aluminous clay, lignite being absent, then three feet of brown clay, containing iron, and underneath struck the iron ore deposit. At Craighill he also found the ore and aluminous clay separated by a dyke. The silica in this clay was in excess, and the lignite absent, except a thin seam at the north-east corner.

According to this authority, at Ballintoy, Limenagh, and Drumnagaster, the clay and pisolitic ore are found under the same roof and conditions; and he thus states:—

"I would here mention that I have usually found the clay and iron ore associated in the same hill or range of hills, and the clay is invariably found to occupy the W. or N.W. portion of the ground. I might also state, a bore hole was put down in the Killymurish Lignite Mines, about eighteen years ago, by a Scotchman called Twist; his journal recorded that after getting through the clay and lithomarge, he passed through nine inches of coal, then nine feet of limestone, then some shale, and afterwards eight feet of limestone. It was a prevalent theory at that time, that the lignite was a true coal, and by boring deeper various seams of true coal might be reached."

This section is very remarkable and unlike anything that has come under my notice; possibly it was in one of the deposits of the iron measures close above the older rocks, such as that at

Craig-na-shoke, due north of Moneymore, recorded at page 159 of "Kinahan's Geology of Ireland."

Usually under the lignite, there is a small band of carbonaceous clay, containing fossil wood, and immediately under this, the altered lithomarge or bauxite; the purest bauxite being on top or nearest the carbonaceous clay, in depth however, it becomes more and more ferruginous, and ultimately, it changes into lithomarge. Small pieces of lignite have been found in the pisolitic ore seam, in the mines near Ballymena, the Mountcashel mines, and rarely in the Glenariff mines, although on the rise of the beds, both towards the north and east at Throstan and Ardeclines, the lignite is found to replace the pisolitic ore, and in such places, the ferruginous pavement of the ore is replaced by aluminous clay or bauxite. The lignite seems nearly invariably to occur at the margins of the basins of iron measures—and if these iron ores are lake deposits, the lignite is the remains of the shore vegetation—and if the main measures, are one great deposit, then, it would seem to be surrounded at its borders or edge by lignite. The accompanying analysis of the lithomarge shows it to be essentially a silicate of iron and alumina. Therefore, as bauxite is a silicate of alumina, the dissolving out of the iron of the bole or lithomarge, would change either of them into a bauxite; hence, it is highly probable, the organic matter from the decaying shore vegetation (now represented by the lignite), dissolved out the iron from the bole and lithomarge.

Intervening between the pisolitic ore (or lignite, where it occurs in the ore seam), and the roof, a steatitic clay and rock called respectively, "holing" and "brushing" usually occur. This steatitic clay, invariably contains numerous pisolites of crystalline aragonite, which are very often partly decomposed into a soft unctuous mass; it seems probable that they were amygdules in cellular basalt, prior to its becoming steatitic; these pisolites of aragonite are not uncommon in the lower dolerite flows. When the iron ore is hard enough for shooting, the steatitic clay is picked out, "holed" (hence the local name), by the miners, causing a vacancy, into which the ore is lifted by the shot, and broken off from the seam.

The steatitic rock over the clay, in places graduates into steatite, and often contains large lumps of white saponite. This rock is from six to eight inches thick, and would come down in

large scales or flakes if not propped. Hence, the local name, as usually, these scales are taken down, that is, cleared or "brushed" off the roof. The brushing is evidently an altered or decomposed dolerite, while the clay is even more altered. They exhibit numerous striation marks, and are more or less laminar; the direction of the stria, so well marked in the Glenariff mines, would possibly suggest, that the flow of dolerite which formed the roof, came from the N.E.

The dolerite roof over the brushing, is quite firm and hard, and requires very little, if any, timber to support it; it invariably exhibits a concretionary structure (or mammillary appearance), similar to that seen above ground, in some weathered beds of dolerite. Here, as in other districts, some beds weather into spheroidal forms, while others decompose in layers, more or less parallel to the original bedding of the stone. The hard dolerite roof of the iron ore measures usually has, protruding from it, crystals of labradorite, augite, and aragonite, the latter mineral is also found filling joints in the roof.

Across the iron ore measures, are dykes, which often displace them; those in the Glenariff district, have general bearings of N.5.E., are perpendicular, or nearly so, and vary from a few inches to several fathoms in thickness. Often they have a more or less columnar structure, the columns lying nearly horizontal, or at right angles to the walls of the dykes. The horizontal joints, as a rule, are regular, extending from wall to wall; while the perpendicular joints are not as persistent or regular. From dykes in which both systems are developed, good building stone can be procured. These dykes in the Glenariff mines, may be divided into two distinct classes; first, those which stop at the roof, or "*stop dykes*," and second, those which penetrate the roof, or "*through dykes*," the latter invariably displace the ore measures, and bake the pisolitic ore seam; while the "stop dykes," neither displace or bake the ore seam. The dykes that stop at the roof, have a parting of steatitic clay, separating them from it, similar to that on the pisolitic ore. All the dykes have a film of steatitic clay at their walls, while the various joints are coated with carbonate of lime. When approaching a dyke, cracks in the pavement are frequently filled with acicular crystals of aragonite; the pavement being much tougher, and contains numerous spots of bauxite, some of them being as large as an

egg. If a dyke is a through one, large crystals of aragonite are common on the roof, the pisolitic ore being also much altered (baked), having in it numerous joints filled with carbonate of lime, and under such circumstances, the ore comes out in blocks, which if broken open, show very little of the pisolitic structure.

The stop dykes usually have a decomposed or soft head, which may extend for two feet in depth, sometimes however, they are quite firm and hard at the top, and are separated from the roof by a small parting of clay only. In Glenariff mines, we have one dyke which comes up and turns over, or "splashes" against the roof, proving it to be newer (see Plate XIX.) The through dykes vary from six to twelve feet thick, and the stop dykes from two to six feet.

On the surface of the ground some of the through dykes can be traced to their termination, that is to the sheet of dolerite into which they join; the dyke No. 6,* in longitudinal section can be seen to pass through the roof and overlying dolerites until it joins into the uppermost sheet. The pisolitic ore where in contact with this dyke is burnt into a hard mass, in which the pisolites can be distinctly seen, though they cleave across with the stone of ore when broken open. The dyke No. 7, which is in a down throw of three feet to the west, and though much thicker than No. 6, cannot be seen on the surface of the ground, only bakes the ore slightly and probably belongs to the flow which formed the roof or the one immediately above it. To the west of this dyke there is scarcely any pisolitic ore, but immediately to the east of it there is a magnificent seam probably the best in Glenariff.

No. 9 is a "stop dyke" which varies from two inches to two feet thick. It is very irregular in its course, and in places appears to have come up with considerable force, and splashed or turned over against the roof as shown in the section; but other parts of it do not come up to the roof. Usually, however, the stop dykes have a soft or decomposed head, the one shown No. 10 is six feet thick, and in places is decomposed for three feet in depth; to the west of this dyke there is scarcely any pisolitic ore; but immediately to the east of it there are two good seams (see Plate XIX.), separated by a few inches of steatitic clay, the top seam is

* This dyke was shown on a map and longitudinal section of the iron ore measures, which is not published with this paper.

red and the bottom one dark-brown; about three fathoms to the east of the dyke the top seam is cut out, while the bottom one increases in thickness.

To the following I would draw special attention in the Glenariff district, I have never found the ore of the same quality and quantity on both sides of a dyke, and from what I can learn the same thing occurs in other mines; as a rule a good seam occurs on one side only which is generally on the east side. To me this appears important as we find a similar phenomenon in standing mineral veins, when the elvans or cross courses appeared to act as a stop to the filling material. Thus in the case of the pisolitic ore seam, it would appear that the dykes which stop at the roof acted as a sort of stop for the material which constitute the ore seam. As previously stated the pisolitic ore is neither baked nor displaced by the majority of dykes which stop at the roof; while nearly invariably it is displaced and indurated by the dykes which penetrate the roof, from which it would appear, that the pisolitic ore was formed prior to the latter, and subsequent to the former. Yet as previously stated, the relation between the iron ore and the lignite, would suggest the accumulation to be lacustrine. But on the other hand, the pisolitic iron seam is not of even thickness, and is often absent over large areas, also its thickening at one side of a dyke and not at the other; the pisolitic structure being well developed in one place and scarcely discernable in another, and the largest pisolites being always found next the roof decreasing both in size and number as we descend from it, are facts difficult to explain in a lake deposit. As however, none of the eminent authorities who have written on these horizontal seams, have put forward a theory that will satisfactorily account for those peculiarities in their accumulation, it would be presumption in me to do so.

Notes added in the Press.

No. 1.

A large plan and section of the Iron Ore Measures was exhibited when this paper was read; also specimens of the various rocks and minerals referred to in the paper, including those showing the division between the first or pisolitic, and the second or aluminous ore, and between the latter and the pavement.

No. 2.

Since writing this paper I found a deposit of manganese accumulating in a mine that had been abandoned for about five years; the water which formed this deposit came through a crack in the roof, from a bog about 200 feet above. The deposit was chiefly found on the sides and floor of the level as a black oozey mass of which the following is an analysis:—

Manganic Sesqui-Oxide,	56·4
Ferric Oxide,	15·8
Lime,	6·0
Magnesia	1·2
Water,	19·7
	99·1

XX.—"BLACK SAND" IN THE DRIFT NORTH OF GREYSTONES, CO. WICKLOW, BY GERRARD A. KINAHAN.

[Read, May 16th, 1881.]

In November of last year (1880) I learned from Mr. James Price, M. INST. C.E., that a quantity of magnetic iron sand had been exposed on the beach north of Greystones, by the heavy N.E. gales that had occurred during the previous month.

When I visited the place, some time after, I found that, for a distance of several hundred yards along the top of the beach, and just at the base of the cliff, there was a quantity of this black sand; it occurred in long patches several inches deep, in one case over twelve inches; but none of it was detected in the cliff, either as a bed or vein.

On a subsequent visit, after the thaw that followed the heavy frost of January, I found that most of the places where the black sand had been observed were covered by the *debris* that had fallen from the cliff; from some of the masses that remained visible, a sample of about 7½ lbs. weight was taken, and subsequently washed. The beach on this occasion in several places was quite black, owing to a thin layer of the sand, from which another sample of sand was taken. This layer of black sand appeared to be due to the wind (which was blowing strongly from the north along the beach) blowing away the lighter sand, and leaving the heavier materials behind.

After the high tides, with N.E. gales, that occurred early in March, I again visited the place, and found that though most of the cliff *debris* above mentioned had been cleared away, yet that none of the black sand, either on the beach or along the face of the cliff, was to be found.

Samples of the drift were taken from several places at different heights along the cliff and panned; in all very fine black sand, but none of the coarser kind, was found; some of the beds of fine sand appeared to be richest in the black sand.

In places through the gravel thin beds of a black material were

observed; these were not found to be any richer in the black sand than the ordinary sand of the cliff, the black colour being due to manganese.

All the samples taken from the cliff were found, on washing, to contain a large quantity of shell fragments, large flakes of mica, and fragments ofquartz. The drift from which these samples were taken consists of an irregularly stratified gravel and fine sand, with patches of a stiff marl appearing through it, and is overlaid by a stiff strong clay. From the very irregular manner in which this drift is stratified, and from the oblique lamination of the beds, it seems probable that during its accumulation there were very varying currents.

In a sample, consisting of about six pounds, of this arenaceous drift, the black sand weighed four grains.

It seems, therefore, that the black sand occurs sparingly, though widely disseminated through this drift, and that its accumulation on the beach is caused by the waves, during certain gales with high tides, washing away the drift cliffs, and sorting the materials according to their specific gravity. It is also very possible that rich layers, or beds, of this sand may occur through the drift, probably towards the base; but none were observed.

When washing, the samples were first passed through sieves which separated them into five degrees of fineness; each of these was washed in a shallow pan, recognizable minerals being picked out during the process, the gold being found in the residue or tailings. These tailings usually had a specific gravity of about 5·0 to 5·2.

The sand yielded about 21·5 per cent. of magnetic material, of specific gravity 4·8, containing magnetite, chromite, and ilmenite.

In the tailings, after the extraction of the specks of gold and magnetic portions, the following minerals were recognised, viz.:—Cassiterite in small grains; red hæmatite, tolerably abundant; brown hæmatite; iron pyrites, rarely unaltered, but there are many small cubes either partly or wholly altered into brown iron; rutile, rare, only a few specks being detected; besides quartz, both rose-coloured and of a light yellow; garnets, very numerous and many-coloured, including various shades of green, yellow, and red. There are also some fragments that appear to be zircons.

In the samples of "black sand" scraped from off the beach, one large scale of gold and five smaller specks were found.

From the sample of $7\frac{1}{2}$ lbs. taken from the foot of the cliff, and washed, thirty-seven specks of gold were obtained; eighteen specks in the finest portion, fifteen in that of the second degree of fineness, and four in that of the third; none being found in the two coarser portions; it, therefore, appears that the gold is all very finely divided.

Gold was found in small quantities in all the specimens of black sand taken from the beach.

Black sands occur at other places along the east coast. In the Museum of the Royal College of Science, Dublin, there is a specimen of magnetic iron sand from Courtown, where, I believe, it occurs between the mouth of the river and the promontory to the south; it also occurs at Ballymoney, north of the last mentioned locality, from which I obtained a specimen with the following description of its occurrence:—

"*Black Sand, Ballymoney Strand, Co. Wexford.*—From a mile to a mile and a half N.N.E. of Ballymoney fishery a thin film of 'black sand' was observed in places lying on the ordinary fine sand of the beach; these patches always occurred in the immediate vicinity of dykes and protrusions of gabbro, and in one place, on the weathered surface of one of the gabbros, the black grains *in situ* were observed as shown in the specimen. The black sand forming the other specimen was skimmed from off the surface of the fine siliceous sand."

The question naturally arises where do these sands come from? Do their constituents occur in the immediate neighbourhood in some mineral vein or channel? or do they occur widely disseminated through the rocks which, by their disintegration, have furnished this drift, and is their occurrence here in such a concentrated form due to local causes?

The occurrence of the sand along such a limited extent of shore suggests that the mother rock is in the immediate vicinity; and from the fact of magnetic iron occurring on the wall of a gabbro dyke, at Ballymoney, it seems not improbable, that the sand at Greystones may be derived from the vicinity of some of the greenstone dykes that occur in the Cambrian rocks, two of which are close at hand; one seen in the railway cutting near Greystones station, the other on the southern slope of Bray Head. But, on the other hand, the associated minerals (quartz, feldspar,

and mica, with very little green grit fragments) point to the mother rock being either a granite or highly metamorphic schist or gneiss, and none of these rocks are known to occur in the immediate neighbourhood. The mother rock may, therefore, be some distance off, and the concentration here of the "black sand" may be due to local circumstances.

The drift in which this sand occurs is, for the most part, very arenaceous, and contains very little argillaceous matter. It appears to have accumulated where there was a prevalence of rapid and varying currents, and may, therefore, be the washings of some previously formed drift, the concentration of the sand being due to the reaction of two or more currents. This question, however, I would leave to more experienced observers to decide.

Note added in the Press.

In analyzing this sand the following method was adopted, viz. :—After the gold specks were picked out several of the concentrated residues were finely pulverized, mixed together, and boiled for some time in strong hydrochloric acid; this was evaporated to dryness (to expel free acid), boiled for some time with water, and filtered. This filtrate, when examined in the usual way, was found to contain lead and copper in very small quantities, iron and alumina in large quantities, chromium, zinc, manganese, lime, and magnesia in small quantities. The portion insoluble in boiling hydrochloric acid was fused with potassic bisulphate ($KHSO_4$), and the fused mass was dissolved in cold water and filtered. This filtrate was boiled so as to precipitate titanic acid, and filtered. That portion of the fusion which was insoluble in cold water was treated with a little dilute hydrochloric acid and boiled and filtered. In this filtrate and in the filtrate from the titanic acid, copper, iron, alumina, chromium, and manganese were found. After treating the fused mass with hydrochloric acid, the insoluble residue was boiled for some time with caustic potash and filtered. From the filtrate tungstic acid was precipitated on acidifying. The residue, after being treated with caustic potash, was fused with potassic cyanide, and from the fused mass a button of tin was extracted.

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CONTENTS.

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Evening Scientific Meetings.

The Evening Scientific Meetings of the Society and of the associated bodies (the Royal Geological Society of Ireland and the Dublin Scientific Club) are held in Leinster House on the third Monday in each month during the Session. The hour of meeting is 8 o'clock, P.M. The business is conducted in the undermentioned sections.

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Secretary to the Section, R. M'Nab, M.D.

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XXI.—A CATALOGUE OF BIRDS OBTAINED IN NAVARRO COUNTY, TEXAS, BY J. DOUGLAS OGILBY.

[Read, February 20th, 1882.]

THE species enumerated in the following catalogue were obtained between the months of June, 1879, and November, 1880, inclusive, in Navarro county, Texas, whose chief town, Corsicana, which is situated about the centre of the county, stands in lat. 32° 5′ N., long. 96° 30′ W. The entire collection was, however, made a few miles to the north of Corsicana, between the towns of Rice and Chatfield, and the Trinity river, in a district which consists about equally of woodland and prairie, the latter intersected by numerous belts of timber, bordering the edges of creeks, which, though dry during the greater portion of the year, form considerable streams after heavy rains; it is bounded on the north and west by the open prairie, on the south and east by the dense timber covering to a depth of several miles, the lowlands on each side of the Trinity river and its feeder Chambers' Creek. With the exception of artificial tanks upon the prairie, and a few small overflow ponds in the river bottom, which connect with the Trinity during the winter floods, there is nothing to attract wading or swimming birds, nor do I know of any permanently marshy place in the neighbourhood, and these facts account for the short stay of most species belonging to either class, and for the non-appearance of others known to be regular migrants or visitors to the State.

Perhaps the most noteworthy feature of the catalogue is the extraordinary mixture of eastern and western forms which occur in this district. Mr. Ridgway, in writing to me from the Smithsonian Institution, says, with regard to an incomplete list forwarded by me to him:—"Representatives of the two faunæ occur in nearly equal proportions, and form altogether a most remarkable assemblage;" and again, "This thorough blending of the two faunæ is more complete than at any other locality of which I have seen faunal lists." With regard to *Sturnella*, for instance, we

have the eastern form, typical *S. magna*, as a winter visitor, while its variety, *S. mexicana*, is our common summer species, and the western lark, *S. neglecta*, seems to be a constant resident, though never in such numbers as the varieties of *S. magna*; it may be observed that the notes of all three are easily distinguishable one from another.

Of individual species the occurrence of *Helonœa swainsoni*, now for the first time recorded from the State of Texas, is worthy of special mention, and it is probable that future observers, on their attention being drawn to the subject, will hereafter detect it as a regular summer visitor, though in limited numbers, to suitable localities, such as the muddy vine-tangled margins of the overflow pools in the river bottom; for, although my specimen was obtained during the last week in August—a time when many of our summer visitors were commencing their southward journey—it is impossible that this district should be in the direct line of migration of a species hitherto known only from the coast region of South Carolina and Georgia, while its occurrence in Cuba suggests that its periodical change of quarters may be performed through the West Indian Islands.

The detection of *Coturniculus lecontei* as an abundant winter visitor is also noteworthy, and certainly gave me more pleasure than that of any other species in the list, as I was not at the time aware of its prior discovery in Cooke county, about one hundred miles further north, while the great difficulty of obtaining specimens increased the zest of the pursuit. In many respects this species seems to be intermediate between *Coturniculus* and *Ammodromus*, the shape of the bill, the length of the legs and feet, which, when outstretched, reach conspicuously beyond the end of the tail, and the greater stiffness and acuteness of the rectrices being characteristic of the latter genus; and, in addition to this, the middle toe, with its claw, is invariably a little longer than the tarsus, a careful measurement of seven examples giving the following average:—Tarsus=0·71; middle toe and claw=0·73. The hind claw also is longer and more attenuated than is the case with the other species of *Coturniculus*. It differs, however, from *Ammodromus* in the shape of the wings, in which the tertiaries are conspicuously longer than the secondaries, and indeed

very nearly equal in length to the primaries. For the above reasons it is probable that it will eventually prove necessary to form a sub-genus for the reception of this bird.

The occurrence of *Peucæa æstivalis* as an autumn migrant in small numbers is also interesting; all the examples obtained belong to the form which has been lately separated by Mr. Ridgway as var. *illinoënsis.*

The great abundance of *Centrophanes lapponicus* and *Neocorys spraguei* in this district was also an agreeable surprise to me, Fort Garland, New Mexico, being the most southerly point from which the former has been recorded hitherto, according to the *History of North American Birds.* (Vol. i., p. 515.) Here, however, it is an abundant winter visitor, accompanying the enormous flocks of shore larks and other longspurs upon the prairie and cultivated lands, and, during severe weather, resorting to the towns, where they may be seen picking about the streets with all the fearlessness and familiarity of sparrows. *Neocorys spraguei,* of which the account is so meagre in the above-mentioned book, is also very common with us, and from the fact that it is only absent during the four months from May to August inclusive, and that young birds in the nesting plumage are common during the fall, it is probable that they do not go much further north to breed.

Among the woodpeckers I obtained one specimen of the red-shafted western form of *Colaptes auratus,* and saw a second a few days afterwards. This seems to be the most north-easterly point where this form has been observed.

Three varieties of the red-tailed hawk are found here, viz., the eastern form typical *Buteo borealis,* which is common and resident; the central or prairie form, *B. krideri,* which is the rarest; and the western melanistic form *B. calurus,* which, though agreeing with its eastern representative in general measurements, differs in many respects in its habits.

The above remarks will serve to show how curious and interesting a mixture of the North American avifaunæ meet together in this district.

In the following list I have adhered strictly to the synonymy of the "Smithsonian Institution Catalogue of North American

Birds, 1881," even where I do not agree with it, considering it better to follow one recognised list than to create confusion by making any change.

? HYLOCICHLA MUSTELINA (Gmel.) *Wood Thrush.*—Examples of the larger speckled thrushes appear to be very rare in this district, so much so that I can mention but one instance in which I am able to record an occurrence with any certainty. On this occasion I was camping out in the Trinity river bottom, during November, 1879, and being my first expedition to the timber, I was unaware of the rarity of the bird, and so let the specimen escape, as the dogs were running a deer up towards our line at the time. It was very tame, and remained perched upon a bough within a few feet of me for a considerable time. It bore a great resemblance to our song thrush, and was almost certainly the species mentioned above.

HYLOCICHLA UNALASCÆ (Gmel.) *Dwarf Thrush.*—A winter visitor to the timber and wooded creeks, arriving early in November and leaving us during March. Between these dates they may be found in small numbers among low bushes and copsewood, and especially in the dense thickets of green brier, the berries of which form a large proportion of their food. They are very terrestial in their habits, delighting to pick about upon the ground beneath thick covert, and scratch among the fallen leaves in search of seeds and berries, which seem to constitute their entire food at this season of the year, no remains of insects having been detected in the stomachs of those which I examined. Though generally found in company with other species, especially those belonging to *Zonotrichia* and *Pipilo,* it is very rare to see more than one of these birds in the same immediate neighbourhood, and should a pair be compelled to take refuge in the same thicket, there is evident jealousy between them. They are shy birds, flitting noiselessly away at the approach of an intruder, though never, if they can help it, leaving the shelter of the clump of bushes which they have chosen as their winter home, and even if driven from it, merely flying up into the trees overhead. They are much attached to particular spots, so that certain places were never uninhabited, while others, to all appearance equally suitable, seemed to hold out no attractions to them; they are partial to the neighbourhood of water.

MERULA MIGRATORIA (Linn.) *American Robin.*—This handsome thrush is an abundant winter visitor, arriving in small flocks about the beginning of November, and at this time frequenting almost entirely the thickly timbered banks of the Trinity river and its tributary creeks, the immediate vicinity of water being necessary to its comfort, for no matter what the temperature may be, they invariably bathe themselves every day after their morning meal, and so regular are they in their habits, that the same pool is visited day after day for this purpose, at precisely the same hour, a fact, the knowledge of which saved me much trouble when I was in want of specimens. I have frequently been amused and interested in watching them perform their ablutions. The whole flock, numbering perhaps as many as fifty individuals, often enter the water together, and, splashing with their wings so as to turn the entire surface of the pool into foam, chattering incessantly meanwhile, playfully chase one another here and there with every sign of the keenest enjoyment, and, finally coming out thoroughly wet, they fly up to the sunniest perch procurable, there to dry and preen their feathers previous to retiring for a midday siesta among the upper branches of the adjacent trees, where they sit so motionless and closely hid that it is difficult to detect a single bird, though every tree in the neighbourhood may hold several. On their first arrival, when berries are plentiful, the robins feed entirely upon them, those of the cedar, mistletoe, the various kinds of grape-vine, and the green brier being most sought after, and it is rare then to see them searching upon the ground for food, but as the season advances and the supply of berries becomes exhausted, they begin to resort to the low-lying parts of the prairie, where the surface of the ground having become soft after the winter rains, they find abundance of worms and snails with which to supplement their vegetable diet, but at no time do they venture to any great distance from the trees, to which, upon any alarm, they immediately retire. The females arrive about a fortnight before the males, but the small flocks in which they perform their autumn migration subsequently coalesce, so that both sexes may be found feeding together; nor did I observe any such separation on their departure, which takes place during the latter half of March, after which month none were seen at their usual feeding

grounds along the edges of the prairie, but it is worthy of remark that when fishing in one of the small lakes in the river bottom upon the 21st April, I saw and watched for some time a pair of these birds, which were evidently mated, though I was unable to find a nest; it is therefore possible that a few pairs may annually remain to breed in suitable localities, where there is a permanent supply of water.

VAR. PROPINQUA, Ridg. *Western Robin.*—Though the great majority of the robins which winter in this section undoubtedly belong to the typical eastern form, I shot examples occasionally which, from the absence of white on the tail and of black markings on the interscapular feathers, combined with the distinctly lighter colouration below, seem to belong to the western form. Indeed, when we consider that *H. unalascæ* is represented exclusively by the western variety, it is unaccountable that *M. migratoria* should be almost as exclusively represented by the eastern, the food of the two species being the same, and each being of equally migratory habits.

MIMUS POLYGLOTTUS (Linn.) *Mocking Bird.*—This is an abundant species at all seasons of the year, though individually migratory, those which breed with us leaving for warmer latitudes during September, while the main body of our winter visitors do not arrive until a month later, the only difference, however, being that our summer songsters are slightly, but appreciably, smaller than their northern relatives, as indeed is to be expected. During the winter they resort to the wooded creeks and edges of the timber, where they find shelter from the biting winds of the open prairie, the effects of which they appear to feel severely; but in the breeding season they frequent detached clumps of trees, tall weeds, worm fences, and especially the neighbourhood of houses far out on the prairie, making every place resound incessantly, by night as well as by day, with their joyous notes, and the evident pleasure which the bird feels in its own song must be manifest to anyone who has watched it when at liberty; utterly unable to remain at rest, in the exuberance of its spirits it flutters its wings, makes frequent leaps, or short flights, into the air, descending again with a semicircular course to the spot from whence it rose, or flits with laboured wing-beats from one perch to another, always selecting the highest available point,

and never for a moment ceasing its song, with which it confusedly mingles the notes of any neighbouring warbler, the cackling of poultry, and even the drowsy hum of the grasshopper, the whole mixed up with its legitimate notes in an indescribable medley; and the fact of its singing equally well in midwinter as in the height of summer proves that its melody is poured forth as much for its own pleasure as for the solace of its mate, nevertheless, at that season, it remains soberly still while singing, and contents itself with a humbler elevation. The nests, which are carelessly constructed of roots, small pieces of stick, wool, and cotton, lined with finer roots and grass, are placed in the most exposed situations, on low trees and shrubs, among coarse weeds, at the corners or junctions of fences, in holes of the woodwork of outhouses, and indeed on any convenient site, at no great distance from the ground, and being greatly exposed to the attacks of prowling cats, skunks, snakes, and other predatory animals, they suffer more severely in this respect than any other species. Three broods are produced in the season, the young of the first being able to fly by the beginning of May, and the usual complement of eggs is five. Their food varies with the time of year, consisting during the breeding season almost entirely of orthopterous insects, while in the fall and winter berries alone are used, the wild grapes being chosen in preference to all others.

HARPORHYNCHUS RUFUS (Linn.) *Brown Thrasher.*—This is a scarce bird in our district, and generally occurs during the cold season, when solitary examples may now and again be seen about the edges of thick underbrush, in which, however, they conceal themselves so quickly and effectually as to make a capture exceedingly difficult. Whenever I did have an opportunity of observing their actions, they appeared to resemble those of the last mentioned species in its restless and uneasy manner, and incessant hopping from branch to branch. When undisturbed, it is, however, much more terrestial in its habits, and is most frequently found upon the ground, scraping among dead leaves, which it throws out to some distance behind it something in the manner of domestic poultry, but always in close proximity to thick covert. Their food consists chiefly of small grasshoppers and berries. It is probable that a few pairs

breed with us, retiring for that purpose to the densest thickets of the river bottom; indeed I shot one specimen early in August, 1880, which was too soon for the migratory birds, since they do not appear until the end of the following month, and which, from its anxiety and fearlessness had, I feel sure, young in the neighbourhood. In June, 1879, I saw a *Harporhynchus* near Richland, which was very much darker in colour than ordinary examples, and may have belonged to one of the other species.

SIALIA SIALIS (Linn.) *Blue-bird.*—Though commonly distributed throughout the wooded parts of our district, this blue-bird is essentially a migrant, those which breed with us passing southward during September, while the northern-bred examples do not begin to arrive in any numbers until about the end of October, and so marked is this interval that during the latter month it is almost an impossibility to get a specimen. They are quite as numerous in summer as in winter, affecting the more open parts of the timber, the edges and outlying copses, and offshoots of the wooded creeks, and mesquite flats, especially preferring places which abound in old decayed trees, and half-rotten stumps, in the knot-holes and woodpecker borings of which they find excellent sites for their nests, which are loose and untidy structures, composed of grass and feathers, laid with no cohesion upon the rotten wood, and generally supporting—for it cannot be said to contain—five eggs. In winter they are even more woodland in their proclivities, and are rarely seen far from the shelter of thick foliage. Though I have examined specimens during every month of the year, I never succeeded in finding any vegetable remains in the stomachs—bees, ants, grasshoppers, beetles and ticks being the ordinary class of food.

SIALIA ARCTICA, Swains. *Rocky Mountain Blue-bird.*—This is the most conspicuous bird upon the prairie during the short time of its stay in our district, as well from its abundance as from its restless vivacity, and the exquisite beauty of its colouration. Arriving during December, they are scarce and sparsely distributed until the end of the month, when they suddenly appear in numbers, swarming upon the detached trees and along the fences of the prairie farms, the latter being the favourite and most coveted situation. From this date until the middle of March, when they all disappear with the same suddenness that marked

the arrival of the main body, the pioneers of which—those which are seen early in December—are invariably adult males. The members of each family keep together during the winter, and each little party having made choice of a particular locality, which, if possible, includes within its bounds a portion of a fence, on which to roost at night and rest during the heat of the day, takes up its temporary abode therein, never straying from the same spot, and exhibiting the utmost jealousy should a member of another family by any chance venture to intrude upon the self-constituted domain, all the members banding together to pursue the stranger with harsh, angry cries to its outskirts. Upon parts of the prairie, however, where there are no fences nor trees on which to roost, this arrangement is modified to suit the requirements of the place, and there seems to be some limit of time to this exclusiveness; for though equally jealous of the intrusion of a stranger during the daytime, after a certain hour of the afternoon they mix freely together, and wend their way in company to some chosen clump of trees in the neighbourhood—those which are devoid of leaves and detached from one another being preferred—and in a similar manner they seek their own haunts in the morning. One such roosting place, which I frequently visited, afforded rest nightly to about two hundred of these birds, and towards sunset, when these were restlessly flitting from branch to branch in search of a suitable twig whereon to pass the night, it formed a sight whose beauty it would be hard to match. They feed upon the prairie very much in the manner of the *Saxicolæ,* to which genus they bear a striking resemblance in many of their habits, much more so than does their eastern congener. Like the chats, they frequently hover in the air for some time with quickly-fluttering wings, but not moving from the same spot, uttering a low and plaintive warbling, while they scan with keen eyes the ground beneath in search of insects, and having discovered one drop down and consume it upon the spot. They are not at all shy, and so bear very close observation without taking alarm. In addition to the song before mentioned, they continually utter a low, clicking note like that produced by striking two stones together, but it is so faint that the listener must be very near to hear it. Unlike *S. sialis,* they are never

found in the woodlands, preferring the open prairie even to the sheltered glades.

Polioptila cærulea (Linn.) *Blue-gray Gnatcatcher.*—This minute bird is an abundant summer visitor, arriving in small parties about the middle of March, and becoming excessively common in all the wooded districts by the end of the month. During the breeding season they escape observation unless closely looked for, as they keep principally among the upper branches of thickly-foliaged trees, and are either quite silent or else their song is so weak that it is overlooked among the host of songsters which at this time enliven the woods; but about August they appear again with their young, and are numerous during the following month, after which none but stragglers are seen. While here they frequent the thickly-wooded creeks and river bottoms —in the latter mostly—affecting the edges of clearings and open spaces, orchards, and such like, and though usually remaining among the higher branches of the trees, showing an evident preference for such as rise from a dense undergrowth of briers and bushes. I found only three nests of the gnatcatcher, each of which was built in a similar manner, placed upon a mesquite at some distance from the ground, and about half-way along one of the main branches, upon which it appears to stand without support, but to which it is in truth most firmly and ingeniously fastened by threads of wool or spiders' webs. The nest, which is deep and cup-shaped, narrower at the entrance than in the interior, is a beautiful structure, composed of fine grass, cotton, wool, Spanish moss, and feathers, woven compactly together and covered thickly outside and sparsely inside with silvery lichens, similar to those with which the branches of the mesquites are clad; and the delicate tints and fragile texture of the eggs make them fully worthy of so fair a resting-place. The first setting of the eggs—four or five in number—is deposited early in May, and the second about the end of June. During the fall they go in family parties, diligently seeking among the upper branches for the small insects which, in their various stages, form their sole food. They are interesting and active little birds, incessantly on the move, hopping from twig to twig, peering curiously into every crevice and cranny of the bark, occasionally even

climbing, creeper-like, up the trunk, or now and then springing into the air after some passing insect, which they are very expert in catching, and continually repeating a low call-note, which serves to keep the little band together. In spring and fall stragglers sometimes occur among patches of tall weeds upon the prairie farms, remote from any woodland, but they never remain long in such places, nor when pursued do they take refuge among the dense foliage of the weed-beds, as do habitual frequenters of such places, but rather keep near the top, flitting from one to another or else go clear away.

REGULUS CALENDULA (Linn.) *Ruby-crowned Kinglet.*—The ruby-crest is a common winter visitor to this section, commencing to arrive about the last week of September, but not becoming numerous until two months later. In the early part of the winter they keep in small parties, frequenting bushes and the lower branches of the loftier trees, and even the heaps of withered branches and dead brushwood upon the ground, but as the season advances, they break up into pairs and gradually seek their food at a higher level, until in March, during which month they are more abundant than at any other time, and after which none remain with us, it is rare to see them upon any except the uppermost branches of the tallest trees. In many of their actions they resemble the *Phylloscopi* more than the *Reguli*, as also does the song. It is one of the most unsuspicious of birds, taking no heed of shots fired in their immediate neighbourhood, nor for a moment ceasing their endless occupation of collecting the minute insects upon which entirely they subsist, and which they will, with the most perfect trustfulness, seek for within arm's length of the observer.

REGULUS SATRAPA, Licht. *Golden-crowned Kinglet.*—A winter visitor in small numbers, occurring from November to March, and frequenting only the thickly-timbered districts and creeks where cedars are plentiful. Like their European analogues, they are restless little birds, going in small parties in company with titmice and tree-creepers, and feeding on small insects, which they find concealed among the branches. They are much less affected by sudden or severe changes of weather than many of our larger and more powerful birds, and even during the hardest frosts are still able to find sufficient food among the upper boughs

of the cedars, the sunward side at least being sufficiently thawed to allow them to carry on their operations successfully.

Lophophanes bicolor (Linn.) *Tufted Titmouse.*—Resident and abundant at all seasons of the year, for though less conspicuous during the breeding season, when they retire to the timber lands in the vicinity of the ponds and rivers, close search will reveal their presence in considerable numbers even then. The only nest which I discovered was formed in an old boring of one of the smaller woodpecker's, about six feet from the ground, and contained young. They are undoubtedly more numerous during the colder months, when they are found wherever there are trees, but especially in the post oak woods bordering the dense timber. They are familiar and amusing little birds, and, having no fear of the hunter, often follow him on his way through the bush, vehemently scolding all the while, and making a frequent hissing noise, similar to that produced by *P. cœruleus,* if disturbed when on its nest. They are also very pugnacious, incessantly quarrelling among themselves, and when fired at and wounded courageously defend themselves, turning on their back and fighting fiercely with beak and claws, and the sharpness and strength of the former is so great as to enable them to draw blood. Like all the family, they are very restless, ever flitting from tree to tree while they examine diligently the trunk and branches for concealed insects, which in summer form their chief food, but in winter, small seeds, and even acorns, which they break in pieces by repeated and quick strokes of the bill, are more sought for. Though its call-note is essentially tit-like, the song, which is very loud and exquisitely clear, bears no resemblance to that of any of the family which I have heard.

Parus atricapillus, Linn. *Black-capped Titmouse.*—This species appears to be merely a scarce autumn migrant to this district, where I met with it but twice, though keeping a careful watch for migratory birds daily during the fall. The first of these occurrences happened on September 23rd, when I shot an adult female, one of a pair, and again, five days later, obtained a male from a small flock in the same place. The stomachs of both these examples contained insects and their eggs. In habits they differ in nothing remarkable from the following species, but in appearance they are easily distinguishable. A female obtained in

March was partly intermediate between the two forms, having the primaries edged with white, as in *atricapillus*, but the tail feathers and secondaries as in typical *carolinensis.*

PARUS CAROLINENSIS, Aud. *Carolina Titmouse.*—This little bird, though resident, is much more common during the cold months, when it is found everywhere in the wooded lands and creeks, while in the breeding season I only observed it along the banks of the river. At the periods of migration examples may not unfrequently be found upon the fences of the prairie farms at some distance from any trees, but they never remain long in such places. Like *P. ater*, which they greatly resemble in habits, they pass the winter by roving about from place to place in small bands, in company with tree-creepers, kinglets, nuthatches and warblers of different kinds, cheering the now leafless woods with their incessant call-notes and sprightly movements. Their food seems to be entirely insectiverous, small caterpillars, and grubs being much sought for.

SITTA CAROLINENSIS, Gmel. *White-bellied Nuthatch.*—Nuthatches seem to be very scarce in this part of the State, since, though continually on the look-out for them, I only observed the typical form on one occasion—upon December 6th—when I came across two small flocks, or more probably the same flock twice, in the high open post oak woods bordering on the prairie; in both cases they were accompanied by titmice, goldcrests, and creepers. They were very tame, taking no heed of a near approach, nor showing the slightest fear of the report of a gun, though discharged just beside them, but running with equal facility up and down the trees, they continued without cessation their search for the insects and grubs which formed their food, and with which the stomachs of those which were shot for examination were crammed.

VAR. ACULEATA (Cass.) *Slender-billed Nuthatch.*—Of this form, easily recognizable by its attenuated bill and obscurely blotched secondaries, I also obtained but one example, but whereas the eastern form occurred in midwinter, this, the western variety, was obtained on June 4th, and among mesquites. It proved to be an adult female, but showed no signs of having bred that season, nor were the eggs developed in the ovaries, for which reasons, and that during two summers I never saw another, I consider it to have been a mere straggler.

Certhia familiaris rufa (Bartr.) *Brown Tree-creeper.*—A winter visitor in small numbers to the open wooded districts and creeks, especially affecting those wherein there is abundance of cedar; in such places they may occasionally be met with between the months of November and March inclusive, accompanying the wandering parties of *Paridæ, Reguli,* and *Dendrœcæ,* which at that season enliven the woods with their presence. It is rare, however, to see more than a pair of creepers with each band; in fact, they seem to prefer the presence of other birds to that of their own species. This, however, is not always the case, since on March 6th I saw a flock of these birds, consisting of more than twenty individuals, and totally unaccompanied by any other species. In habits they resemble the European form, like that bird feeding upon small insects, which they find concealed in the crevices of the bark; alighting almost always near the root of the tree, they run quickly up the boll, usually, when undisturbed, in a spiral direction, and having thus ascended the main trunk until beyond the insertion of the larger branches, they take flight to the foot of the next tree, and there resume their operations; if, however, they should find themselves followed, they keep circumspectly upon the opposite side of the tree from the pursuer, only glancing cautiously round now and then to prevent too near an approach; they are, in fact, at all times wary, and display considerable prudence and knowledge of danger.

Thryothorus ludovicianus (Gmel.) *Carolina Wren.*—This handsome and sprightly wren is resident, but nowhere abundant, in our district, frequenting the wooded parts, where it delights to creep about among thick underbrush and the decaying tops of fallen trees, among which it is exceedingly difficult to obtain, as it keeps carefully on the side remote from danger. They never fly far at a stretch, moving, when compelled, by several short flights, and are, from choice, very sedentary in their habits, seldom moving away from their chosen haunts; nor do they ever rise by flying into the branches of trees, though occasionally they climb thither up the trunk like a creeper. Except during the latter part of the summer, when the young, of which they have at least two broods annually, have not yet left them, they are usually found in pairs, and show great affection for one another,

so much so that I have seen the mate of one which I had shot almost allow itself to be caught sooner than leave the lifeless body of its comrade, and even when that was packed up and put away for safe carriage home, follow me for some distance through the woods with complaining cries. The form found here does not appear to be so large as ordinary eastern examples, and is appreciably darker in colour below, being thus intermediate between *Ludovicianus* and *Berlandieri*.

TROGLODYTES AËDON PARKMANNI (Aud.) *Western House Wren.*—An autumn migrant, arriving about the last week of September. This species, for the space of three weeks, is very numerous in all the wooded creeks, and even outlying copses upon the prairie, but does not affect the thickly-timbered districts. They feed among the coarse grass and broom weeds growing along the edges of the creeks, and, if possible, prefer to conceal themselves among such when approached, never showing themselves unless nearly trodden on, upon which they fly up into the nearest tree, and, after one sharp glance at the intruder, make their way to the further side by hopping from twig to twig, and from thence they flit away so quietly as almost to defy observation, until having put sufficient distance between themselves and the threatened danger, they drop down into the brushwood and conceal themselves so carefully as to be rarely visible again. During the spring migration I only obtained a single example, and from the shortness of its wing, which measured but 2·02, I am inclined to think that this may have been typical *aëdon;* of the many specimens of *parkmanni* which I measured, the shortest wing measured 2·14. The spring specimen was killed among grass on the open prairie, far from any trees or brushwood.

TROGLODYTES (sp.) [?]—A small wren, probably *hyemalis,* is occasionally seen in the wooded districts during the winter months. It differs materially in habits from the last mentioned species, being only found in damp, open woods, in the river bottom, and exhibiting a decided preference for piles of dead logs over all other localities, and so cunningly did they creep between and conceal themselves in such debris, that I never succeeded in obtaining a specimen.

CISTOTHORUS STELLARIS (Licht.) *Short-billed Marsh Wren.*—This pretty little species occurs in limited numbers on the prairie

during October, frequenting long coarse grass and weeds, remote from trees, among or on which I never knew it to alight. They are difficult to obtain, as from the nature of their haunts it is nearly impossible to catch a glimpse of them when at rest, and even when forced to fly, which of itself is no easy matter, they go but a few yards before dropping again into covert, among which they either run off or conceal themselves so effectually as to elude the most careful search. Occasionally, however, if perfect stillness be observed, they may be seen creeping up the stems of the coarser plants, and examining them closely for the small insects which form their principal food; on one occasion I found a grasshopper quite entire and so large that it seemed a miracle how so tiny a thing could have captured and swallowed it. I found these wrens more frequently upon the upper ridges and slopes of the prairie than in the damp hollows.

Anthus ludovicianus (Gmel.) *American Pipit.*—An abundant winter visitor to the open districts, where it makes its appearance in enormous flocks about the middle of October, but soon breaking up into parties of from ten to twenty individuals, they scatter themselves over the whole country, frequenting cultivated and fallow fields, dry upland and low-lying damp prairie indiscriminately; so they pass the time until February, when they again gather in large and continually increasing numbers, and resort to the newly-ploughed lands, where they prove of the greatest service to the farmer by the destruction of the noxious grubs and insects which he turns up; in such places they remain until about the second week in April, when they all suddenly disappear. These pipits show no marked partiality for the neighbourhood of water, nor did I ever see them wade into or even feed along the edge of the prairie pools, but, on the contrary, they seem to prefer, if anything, a dry sandy or gravelly soil. Their movements on the ground and on the wing, as well as their peculiar, short circular flight while singing, are exactly similar to those of our common British species, as also is their call-note, uttered when rising. They are very much given to alighting on trees, especially in the morning and evening, so that I have frequently killed several at a shot, and indeed I have so often observed flocks upon solitary trees at so late an hour that I believe that they intended to pass the night in that position.

Their food consists almost entirely of insects chiefly in the grub stage, but occasionally a few small seeds are to be found.

NEOCORYS SPRAGUEI (Aud.) *Sprague's Pipit.*—This pipit is one of the most plentiful of the cold weather visitors to the barer districts, arriving in pairs or small family parties during the latter half of September, and inhabiting the most sandy and barren parts of the prairie in preference to the cultivated fields, and in all cases avoiding the vicinity of trees; and, as the winter advances, they become even more unsocial in their habits, so that it is very rare to see more than a pair together, though they are all mated by the end of April, when they leave us. In most of their actions they are eminently pipit-like, but their call-note is shriller and wilder. They are not nearly so unsuspicious as the brown pipit, and are more difficult to obtain, since, when approached, they run behind the nearest tussock of the coarse grass which sparsely covers the barren uplands which they delight in, and there, with head stretched out to full length, they squat down as close as possible to the ground, to which their colours assimilate so well, that it is almost impossible to perceive them unless they move; but, if too closely approached, they rise with a sudden spring, and after flying for a few yards parallel to the surface, they wheel sharply to one side and upwards, greatly quickening the pace at the same time, and so rise in gentle undulations until they have attained a height of about one hundred yards, when, after circling for a few minutes overhead, they suddenly close their wings, and, dropping like a stone to earth, alight at once and squat as before; if, however, much disturbed, they frequently protract their flight out of sight. Their food consists of grasshoppers, smaller insects, and sometimes seeds.

With regard to the generic peculiarities of *Neocorys*, it is certainly a mistake to say that the rictus is without bristles; though not so long as in typical *Anthus*, these bristles are easily apparent in fresh specimens, and of the numerous examples which I examined carefully, but two had the outer primary longest, the most usual gradation of the outer four being 3, 2, 1, 4. The most notable difference in size and form between this and *A. ludovicianus* is the enormously enlarged foot of *Neocorys*, in which both middle and hind toes (including their claws) exceed the tarsus. With this exception, there is little difference in the

size of the two birds, *Neocorys* being slightly the smaller, but, from the greater stoutness of the body, it exceeds its relative in weight. I append a table showing the average measurements of twenty individuals of each species:—

	Length.	Wing.	Tail.	Tarsus.	Mid, toe.	Hind Toe.	Bill from Nostril.	Weight.
N. spraguei, .	6·40	3·22	2·55	0·87	0·90	0·97	0·32	0·87
A. ludovicianus, .	6·60	3·37	2·75	0 86	0·78	0·77	0·35	0·77

Mniotilta varia (Linn.) *Black and White Creeper.*—This is a summer visitor to our district, but is everywhere so scarce that I obtained but three examples, occurring in March, July, and September, and it was during the latter month alone that I observed them in any numbers, when on migration in company with other warblers and titmice. They are expert climbers, creeping with ease up the trunk and about the branches of trees, and keep more to the open woods and creeks than to the dense thickets.

Protonotaria citrea (Bodd.) *Golden Swamp Warbler.*—Arriving during April, this species is by no means uncommon in suitable situations during the summer months. Evincing a decided preference for the neighbourhood of water, a few pairs may be found any day in the low, damp thickets along the banks of the river, and especially about the margins of the muddy ponds. It is an unsociable bird, generally solitary, or, at most, in pairs, even during the fall, when most species are educating their young, and is unsuspicious, taking slight notice of an intruder, and so little heeding the discharge of a gun that I have known them on several occasions fly up to the sportsman and alight on a tree beside him, as if impelled by curiosity. It is slow in all its motions, hopping from branch to branch with a marked deliberation unusual among the members of this sprightly family; and it is also exceptionally silent, rarely uttering more than a single clear note. Its food consists entirely of insects, which it seeks for both upon the lower branches of trees and bushes and on the ground. None remain with us after the end of August.

Helonæa swainsoni, Aud. *Swainson's Swamp Warbler.*—I obtained a specimen of this rare warbler—the only one as yet recorded from the State—on the 24th August, 1880, upon the banks of a small pond in the river bottom. When first observed

it was sitting on a bough overhanging and almost touching the mud along the margin, and the bushes being very dense and itself so tame, I was obliged to fire at it so close that it was very much torn by the shot. The head, however was entire, and, on picking it up the curiously-shaped sharply-ridged bill at once attracted my attention. Its movements in hopping from one twig to another were sluggish, and it uttered no sound of any description, and its stomach contained only a very few small insects.

HELMINTHOPHAGA RUFICAPILLA (Wils.) *Nashville Warbler.*—During the month of October I found this pretty little species not unfrequent in the creeks and open woods along the edge of the prairie. They were more unsociable and solitary than any of their family, being usually found singly or in pairs, and though occasionally half-a-dozen might be seen together, I never observed them associating with the bands of migratory birds at that time passing, but rather keeping exclusively to themselves. They feed upon insects and small caterpillars, which they seek among the middle and lower branches of the trees, and even upon low stunted shrubs.

PARULA AMERICANA (Linn.) *Blue Yellow-backed Warbler.*—I met with these beautiful little birds only during the month of August, 1880, when they were not uncommon in the thick woods, and occasionally even in the creeks on the prairie, always going in small parties, and usually accompanied by *Polioptila.* In their manner of feeding they resemble the titmice, hanging in every conceivable attitude to the lower branches of the trees, especially near the end, and searching every leaf and twig for the insects, larvæ, and eggs upon which they feed. Their confidence, beauty, and the gracefulness of their movements, make them one of the most attractive of birds.

DENDRŒCA ÆSTIVA (Gmel.) *Summer Yellow Bird.*—This conspicuous bird is an irregular migrant through our district, sometimes appearing in considerable numbers, and again either very scarce or not at all. I first made its acquaintance upon August 12, 1879, and from that time until the middle of the next month I found it common in the mesquite flats, outlying copses, and solitary trees on the prairie, but never saw one in the woodlands, or even in the creeks. I observed them again on their return in May, but not in so great numbers, and at this season

they seemed to prefer the beds of tall sunflowers on neglected farms, though I still remarked their partiality for mesquites. During the fall of 1880, when I was anxious to procure some skins, I kept a special look out for these birds, but did not see a single example.

Dendrœca coronata (Linn.) *Myrtle Warbler.*—Arriving during the latter half of October, these birds are very abundant in our section from that time until the third week of March, beyond which I never observed any. During the winter months, they frequent the creeks and open woods, feeding in cold or stormy weather upon the lower branches of trees, and even among low brushwood or heaps of dead boughs lying on the ground, but quickly returning to their favourite haunts among the topmost twigs, with the first show of returning warmth, but as the spring advances, they come much more out upon the prairie, resorting to the clumps of mesquite along the edges of the creeks, and even to the fences of the prairie farms, where they feed, for the most part, upon winged insects, which they seize while in flight, with great expertness, returning again and again to the same perch, like a true flycatcher. They are, at all times, active and restless birds, but especially so at this season, when they are continually on the move, either chasing one another here and there or pursuing the passing insects. At this time they have mostly broken up into pairs, but during the winter they go in small flocks, in company with kinglets and titmice, which latter they resemble in the manner of their feeding and also in their call-note. Their food at this time consists in great measure of various berries and seeds.

Dendrœca maculosa (Gmel.) *Black and Yellow Warbler.*—On the 15th May, 1880, I obtained my first and only specimen of this beautiful little bird. It occurred in company with several pairs of *Myiodioctes pusillus*, in a small patch of weeds along the fence of a farm upon the prairie. I found it exceedingly difficult to obtain, from the persistency with which it kept among the densest growth of the weeds, never for a moment rising above them. It proved to be a female, with the stomach filled with minute insects.

Dendrœca blackburniæ (Gmel.) *Blackburnian Warbler.*—I obtained a few specimens of this handsome warbler during the

latter half of May, in the creeks and detached copses upon the prairie. I always found them in pairs, and very affectionate, keeping close together, and apparently feeding one another; they seem to prefer the upper branches of small or young trees to those of a greater altitude, and are not so restless in their habits as *D. coronata.*

Dendrœca dominica (Linn.) *Yellow-throated Warbler.*—I obtained but one specimen of this warbler, which I found upon the 20th March, 1880, feeding among the loftiest branches of a tall tree in company with *D. coronata* and *R. calendula.*

Siurus nævius (Bodd.) *Small-billed Water Thrush.*—I shot my only specimen of this warbler at a tank upon the open prairie, on September 13, 1880. The situation, which was far away from any trees, shows that it was merely a passing migrant. It was very fearless, running about and feeding close to my feet, and was most adroit in catching the small water beetles along the shallow margin of the tank. The difference in size, especially of the bill, between this and the next species is very appreciable.

Siurus motacilla (Vieil.) *Large-billed Water Thrush.*—A summer visitor, but nowhere very common. This handsome and interesting little bird may be found any day between the middle of March and the end of August along the most undisturbed parts of the banks of the river, and about the muddy edges of the woodland ponds. Always shy, and anxious to shun the neighbourhood of man, it is not easily watched, as the approach of an intruder causes it instantly to dive into the recesses of the thicket, from whence it does not emerge until all is again quiet. They feed along the edge of the water, like the smaller sandpipers, picking up insects, and even wading a short distance in to take them from the surface, occasionally also catching them on the wing. They run most adroitly over half-submerged logs and branches, from the decaying wood of which they extract a rich harvest of eggs and larvæ. I never saw them alight on any except the lowest branches of trees and bushes, and generally those alone which overhung the water.

Oporornis formosa (Wils.) *Kentucky Warbler.*—A summer visitor, arriving about the beginning of April, and frequenting in small numbers the densest and shadiest thickets along the banks

of the river. It is very terrestrial in its habits, rarely rising above the lowest branches of the trees, and preferring to seek for insects and larvæ among the dead leaves and twigs which strew the ground in such situations, and where opportunities for observing them but seldom occur, as in the presence of man they are shy and quiet. I never met with them after the end of August.

GEOTHLYPIS TRICHAS (Linn.) *Maryland Yellow-throat.*—This handsome little warbler is a summer visitor to the open districts, wherever there is a sufficient growth of weeds and low stunted bushes to afford it the shelter and concealment which it needs. They are most abundant during the spring and fall, especially in September, when almost every patch of weeds holds its family party, but a few pairs certainly remain to breed, resorting for that purpose to the edges of dry watercourses, especially in rich land. The only nest which I found was placed among tangled roots of weeds, about a foot from the ground, and was, unfortunately, torn down and destroyed by some prowling animal, after the deposition of one egg. It was composed externally of dry sedge and weeds, and rather sparsely lined with fine grasses. The stomachs of those which I examined were filled with insect remains, among which the brilliant green elytra of small beetles were always conspicuous. They generally keep near the ground, seldom indeed rising above the summits of the weeds, unless close pressed.

MYIODIOCTES MITRATUS (Gmel.) *Hooded Warbler.*—I only obtained two specimens of this bird, both of which occurred during the latter part of August. It is, however, probable that they are regular summer visitors to the dense and impenetrable jungles of green brier in the river bottom, in the recesses of which they escape observation. The two procured were very tame, flitting before me down roads cut through the thicket, and perching only on boughs near the ground.

MYIODIOCTES PUSILLUS (Wils.) *Black-capped Yellow Warbler.*—This species occurs in our district at the periods of migration, passing northwards in small numbers during May, when they frequent the weed beds on neglected farms, but, on their return in September, they principally resort to the creeks and open woods, wandering about in small family parties along with

titmice and *Dendrœcœ,* and quite as active and restless as they are.

MYIODIOCTES CANADENSIS (Linn.) *Canadian Fly-catching Warbler.*—I obtained a single example out of a small flock during the last week of August, 1880, among low densely-foliaged shrubs along the banks of the river. They were lively little birds, busily seeking for insects among the lower branches of the thicket, and were quite unsuspicious of approach.

VIREOSYLVIA OLIVACEA (Linn.) *Red-eyed Vireo.*—An abundant summer visitor to the densely wooded districts, where it arrives about the beginning of April, and from that time to the middle of September is one of the most conspicuous inhabitants of those leafy solitudes. They are active and restless little birds, continually, even under the scorching blaze of the noonday sun, in motion amongst the upper branches of the loftiest and most thickly foliaged trees—a situation which they peculiarly affect—never while here descending near the ground. Their food consists of insects, which they occasionally take upon the wing, but more commonly while resting; nor did I find a trace of vegetable matter in the stomachs of those which I examined, either in spring or fall. They are persistent singers, bursting forth continually into song, even when engaged in procuring food, the notes being clear and sweet, and very loud for the size of the bird.

LANIVIREO SOLITARIUS (Vieil.) *Blue-headed Vireo.*—On the 4th October I shot an example of this bird in the bottom timber where it was feeding among the middle branches of the trees, in company with a few of its own species, kinglets and titmice; its stomach was full of small coleoptera. This was the only occasion on which I met with it.

VIREO NOVEBORACENSIS (Gmel.) *White-eyed Vireo.*—An abundant summer visitor to all the wooded regions, where it arrives during March, and immediately sets about the duties of incubation, the first brood being able to fly by May, and the second by July. They have all left this section by the middle of September, for a month previous to which date they are by far the most numerous of the woodland birds, and are very conspicuous, going in parties of from ten to twenty, and feeding among the lower and middle branches of the trees. During the spring and summer they feed entirely on insects, small caterpillars being

always present, but in the fall they change to a vegetable diet, eagerly consuming seeds and berries. They are quite fearless in defence of their young, flying up to the intruder with incessant chatterings and scoldings, and even when feeding exhibit no uneasiness at a close approach.

Vireo belli, Aud. *Bell's Vireo.*—A common summer visitor to the prairie, frequenting small isolated clumps of low trees or bushes, and beds of tall weeds, and never resorting to true wooded districts, though occasionally seeking their food among the branches of single trees. They never fly far at a time, usually proceeding but a few feet, and then again dropping out of sight. They arrive about the middle of April, and are very accurate in the time of their departure, the 12th August being the last occasion on which I observed them during two seasons. They feed principally upon insects, but a few seeds may often be found mixed with these. The nests, which are beautiful little structures, are suspended from two or three small twigs, near the end of a branch, or from the finer stems of weeds, several of which from different plants are often brought into requisition; they are formed of withered grass and leaves, with a little wool and cotton sometimes intermixed, bound together and to the substances from which they hang by spiders' webs, and always lined with fine dry grass. They bring out two broods in the season, the eggs being four or five in number. The nests and their contents suffer greatly from predatory animals.

Lanius ludovicianus, Linn. *Loggerhead Shrike.*— This species, which from the similarity of colours is generally called "Winter Mocking-bird" here, is an abundant winter visitor to the prairie, where it arrives early in August, from which time until October they pass further south in a continuous stream; they remain common but stationary during the winter, not beginning to show symptoms of the northern migration until March, and by the end of the following month all have disappeared. These are most unsocial birds, not only showing the greatest antipathy for the proximity of any members of their own race, but also pursuing any other bird which may venture near their perch, even *Milvulus forficatus*, the tyrant of the prairie in summer, having to yield ignominiously. They chiefly haunt fences and solitary trees, as mesquites, upon the prairie,

choosing each a special perch—always one of the uppermost twigs—from which it commands an uninterrupted view of the surface of the surrounding ground, and from whence they dart down upon any insect whose movements may attract their keen eyes; they always carry their prey back to their perch before consuming it, unless when not hungry at the time, when they impale it upon some neighbouring thorn. The introduction of barbed wire for fencing prairie farms suits them, as one may judge from the number of insects often found impaled thereon. Grasshoppers and beetles are their ordinary food, but that they occasionally hunt and kill small or wounded birds, I have, on two occasions, been an eye-witness, the first being a song sparrow, the second a wounded mocking bird—both, when examined, had the back of the skull crushed in. They sometimes take large insects on the wing, returning, flycatcher-like, to the same perch, and I have even seen them, while moving from one place to another, arrest their course in order to pursue passing insects. They sit bolt upright on their perch, looking like a small hawk, and, when disturbed dart down to within a short distance of the ground, and flit along with a low, wavy, and rapid flight, until almost immediately beneath the selected twig, when they shoot suddenly upward and alight at once.

VAR. EXCUBITORIDES (Swains.) *White-rumped Shrike.*—Occasionally in the fall I have obtained shrikes, which, from the continuance of the white patch on the tail, and the slightly greater length of the tarsi, are probably referable to this form. They differed, however, in none of their habits from their more numerous brethren.

AMPELIS CEDRORUM (Vieil.) *Cedar Bird.*—This beautiful bird is an irregular winter visitant to the district. During the winter of 1879–80 I did not observe a single specimen, but early in December, 1880, they suddenly appeared in small flocks in all the wooded lands and creeks, and from the time of their arrival until my departure, towards the end of the month, scarcely a clump of cedars which I passed in my rides wanted its flock; and they bore testimony to the correctness of their name by feeding exclusively upon the berries of that tree. They are tame birds, only rising when fired at, and, after circling about for a few seconds, re-alighting on the same or a neighbouring tree. Their flight is

strong, and, while feeding, they are excessively graceful in their motions among the branches.

Progne subis (Linn.) *Purple Martin.*—This large and powerful swallow is an abundant summer visitor to the inhabited parts of the more open districts, and is especially numerous in the neighbourhood of towns and villages, where most of the houses are provided with boxes for their accommodation. They begin to arrive about the last week of March, and immediately set about the choice of a box for nidification; this is accomplished with very little bickering, although several pairs may choose compartments under the same roof; they lay a foundation of straw, grass, twigs, and similar materials carelessly heaped together, and line it softly and warmly with feathers and cotton; the eggs are pure white, five in number, and two broods are raised in the season. This is one of the first birds to leave in the fall, none being seen after the middle of August. On the open prairie they are much more scarce than in the thickly populated lands, doubtless owing to the want of suitable nesting places, since, when a box is put up in a new locality, however isolated, it rarely remains long untenanted; and it is to be remarked that these new settlers are invariably birds of the preceding year, the male being still clad in the dull plumage of immaturity, which he does not lose until his second moult. From this fact it may be inferred that each pair returns annually to the same box. They are encouraged in every way about the prairie farms, from a belief that they drive away hawks from the neighbourhood of the houses which they frequent, and they amply repay their protectors by the destruction of insect pests, of which they consume enormous numbers; indeed, from a careful computation arrived at by watching the birds feeding their young at different hours in the day, I conclude that each pair and their brood consume at least one thousand insects daily.

Petrochelidon lunifrons (Say.) *Cliff Swallow.*—The cliff swallow arrives with us about the end of April, and for the next three weeks may be seen almost every day passing in small flocks, their flight having a general north-easterly direction, though they continually hawk for insects as they go. Their return flight, for they certainly do not breed in this neighbourhood, is accomplished in a most erratic manner; for instance, on July

3rd, I saw a flock of several hundreds, and from that date until well on in August what I take to be the same flock daily frequented the same stretch of prairie, passing in the morning to the westward, and in the evening returning over the same course to the woodlands where they roosted. After their departure I saw not a single one until the 10th September, when about a score passed me, flying south, nor did I see more than two or three single birds until the 21st, when I witnessed a most extraordinary migration—a flock passing the house which must have consisted of many thousand individuals, forming a continuous stream which lasted for more than two hours, the air being thick with them the whole time. A few days later I saw a similar flock, but not so large, and then only a few every day until the 2nd October, after which I observed no more. All these were passing towards the south-east.

HIRUNDO ERYTHROGASTRA, Bodd. *Barn Swallow.*—Owing to the want of suitable breeding places, the barn swallow is merely a passing migrant in spring and fall, and even then in very small numbers. They never appear in flocks, like the last species, but always singly or in pairs, and passed northwards in April, but during that month they were so scarce that I did not see more than a dozen examples, while on the return migration, which lasts from the middle of August to the end of September, few days passed on which I did not see as many. Their line of flight is always due north and south, and is much more direct and continuous than that of any other of their relatives when migrating.

TACHYCINETA BICOLOR (Vieil.) *White-bellied Swallow.*—This beautiful species is for the most part only a spring migrant in this section, and is the first of all its family to arrive on the prairie, where a few pairs appear early in March, and during the latter half of that month and the whole of the next they are common, while even during May a few straggling pairs occur at irregular intervals. It is possible that some few may even remain to breed so far south, as a pair undoubtedly frequented the neighbourhood of a clump of isolated trees upon the prairie during the month of June, but I never was able to detect any signs of nidification. Like many other birds, their fall migration must move along some other parallel, as they never appear in this district at that season.

COTILE RIPARIA (Linn.) *Sand Martin.*—Unlike the last-mentioned species, this martin only occurs on its southward migration, at least in any conspicuous numbers. They are most frequently associated with the flocks of *Petrochelidon lunifrons*, but never in any numbers. I observed them first about the end of July, and from that time until the middle of September not a day passed without my seeing them. They were quite plentiful about the middle of August. The stomachs of those which I examined were filled with small black beetles.

PYRANGA ÆSTIVA (Linn.) *Summer Red-bird.*—This species is found only in the thickets of the river bottom, to which it is a summer visitor, arriving about the middle of April and leaving by the end of August. It is a shy, unsociable bird, much more frequently heard than seen, notwithstanding the conspicuous plumage of the adult male; even before they leave this country the young seem to wander off from their parents. Their food consists of large insects, beetles, grasshoppers, grubs, &c., and in the fall of various berries. Though generally found among the branches of trees, they prefer those whose stems are surrounded by thick underbrush to the more open woods.

ASTRAGALINUS TRISTIS (Linn.) *American Goldfinch.*—This beautiful little finch is a very common winter visitor to the county, where it arrives about the middle of October, and frequents the wooded creeks on the prairie, mesquite flats, and weed beds on neglected farms. In such places they prove of the greatest service to the agriculturist, by feeding greedily on the seeds of the broomweed, sunflower, and other noxious plants, but in the creeks they feed on the seeds of different trees, which they break up into small pieces before swallowing, catching each piece of the kernel as it flies off with great expertness. When a flock is so engaged among the branches of a tree, they are, as a rule, perfectly silent, but make as busy a picture as it is possible to imagine, while the pieces of shell, &c., cast away in their endeavour to get at the kernel, fall with a continuous clatter among the dead leaves below. When not engaged in feeding, they make long circling flights above their haunts, or settle upon the summit of some lofty cottonwood in the neighbourhood to enjoy what warmth they can obtain from the winter sun. They are always very tame, scarcely flying away at the report of a gun, and even

though some of their number be killed, at each discharge returning again and again to the same tree. They leave this district by the end of February.

Chrysomitris pinus (Wils.) *Pine Finch.*—The pine finch is a winter visitor to this part of the State, and even then seems to be very scarce; nevertheless a few straggling examples may occasionally be observed associated with the wandering flocks of *Astragalinus tristis*, which species it resembles in its habits and mode of feeding, except that it shows a greater preference for the seeds of trees than for those of the weeds; it is, therefore, a more decidedly woodland bird. It does not, however, penetrate into the deep timber, but haunts the creeks and edges of the woods and glades. I only observed them between the last weeks of November and January.

Centrophanes lapponicus (Linn.) *Lapland Bunting.*—This species is a very common winter visitor to the prairie, where it makes its appearance during the latter half of November in flocks of almost incredible numbers, and spreads itself at once over the bare level districts in company with *Rhynchophanes maccowni* and *Eremophila alpestris.* They evince a decided partiality for moist upland localities, though fallow and stubble fields are also frequented, and they are accused of doing much damage to the growing wheat. This, however, is certainly an error, as seeds of various grasses and weeds, especially those of the noxious broomweed, formed the only food of the numbers which I have examined. They remain with us for a much shorter time than the other longspurs, none being observed after the first week in March. Their flight is peculiar and unmistakeable—rising with a quick spring from the ground, they ascend at once to a height of about one hundred feet, and fly round for a short time in an aimless and desultory manner; then, suddenly dashing down with extraordinary velocity to within a few inches of the ground, they become transformed from a long, straggling body to a compact and organized mass: thus they stream along immediately above the tops of the herbage, often for several hundred yards, when, on a sudden, the foremost bird alights, and, quicker than thought, every other individual drops wherever it may be; occasionally, however, and especially towards evening, they rise again and repeat the whole performance; if, however, they alight they waste no time looking about them, but immediately

set to work searching for food. They run swiftly and gracefully, and are wonderfully expert in extracting the seeds of weeds, such as broomweed, which are too tall for them to reach while standing on the ground. Placing themselves below the coveted food, they take little leaps, at each effort withdrawing a seed so expertly that not a movement of the plant can be detected. During severe weather I have seen these birds seeking for stray pickings in the streets of Corsicana, along with shore larks. So numerous are they at some seasons, that I have killed sixty-three longspurs at one shot, fifty-eight of which belonged to this species.

CENTROPHANES PICTUS (Swains.) *Smith's Longspur.*—These birds, which differ from their relatives in their marked preference for upland dry stretches of prairie, arrive with us during the third week of November, and soon become common in all suitable localities. They do not go in large flocks, but rather in pairs and family parties, and frequent the edges of roads and bare sandy places, diversified with tussocks of coarse grass, such as *Neocorys spraguei* haunts. Even when a considerable number are in the same spot, they do not feed or fly together, but each takes his own course; they rise with a quick, jerky, irregular flight to a considerable height, and after a few minutes' circling in a vague and uncertain manner, drop to the ground like a stone, and immediately conceal themselves in or behind the nearest tuft of herbage so completely that it is quite impossible for the eye to distinguish them, and here they lie so close as almost to allow themselves to be trodden upon; when rising, they utter a quick musical twitter. They have all left this district by the middle of March. This species seems to live entirely upon the seeds of various grasses; it is never found upon cultivated lands.

CENTROPHANES ORNATUS (Towns.) *Chesnut-collared Longspur.*—I met with this beautiful species first in the last week of January, 1880, when I obtained a male from a flock of *Rhynchophanes maccowni.* From this time I saw no more until the beginning of April, when they suddenly appeared in large flocks, frequenting only the most sandy and barren parts of the prairie, and feeding indiscriminately on seeds and insects. Unlike the last species, they keep very close together while feeding, the whole flock moving in the same direction, and as those from the hindmost

ranks are continually flying a few feet forward over the heads of those in front, they look more like a number of small mammals than birds. I saw none after the middle of the month. All those which I obtained were in the plumage originally separated by Professor Baird as *Plectrophanes melanomus.*

RHYNCHOPHANES MACCOWNI (Lawr.) *McCown's Longspur.*—These birds are very common visitors to the prairie, arriving about the beginning of November in large flocks, which for the first three weeks of their sojourn consist entirely of females, but upon the arrival of the males the different flocks amalgamate, forming, under favourable circumstances, bands of almost incredible number, so much so that the noise made by the wings of the assembled multitude when rising and settling may be heard at a great distance. The members of the flock keep very close together in flight, sweeping along something in the manner of a flock of plover, now showing all silvery white as the lower parts alone are exposed to view, and anon darkening until they become almost invisible against the surface of the prairie, as their backs are turned to the spectator; the tail, which is frequently expanded when in flight, betrays the species at a glance, from the large amount of white which stretches entirely across it. They remain with us until the end of March, and during that month are by far the most abundant small birds, frequenting the low-lying, damp and flooded parts of the prairie, where they feed chiefly upon the seeds of grasses and weeds, but also upon small insects. They frequent the cultivated fields as well as the prairie, and are often found in company with shore larks and Lapland buntings. The total length 5·50 inches, given in the "History of North American Birds," page 523, is that of a very small individual; adult males are often more than an inch in excess of that size.

PASSERCULUS SANDWICHENSIS ALAUDINUS (Bonap.) *Western Savannah Sparrow.*—A winter visitor in large numbers, frequenting the open districts, and never found even in the glades and cleared lands of the river bottom. They arrive with us about the beginning of October, but are not common until the end of the month. They frequent the cultivated lands, especially preferring those on which a rank undergrowth of coarse grass and weeds has been allowed to spring up, but are

also found upon the open prairie, along the edges of roads and watercourses, and in the mixed land, about the junction of the timber with the prairie. When put up, they fly only a short distance, and then drop into a bunch of grass, where they remain hidden until the danger is past, but if again approached, they seek to escape by running, which they are able to accomplish with considerable swiftness, nor unless close pressed will they again take wing. I have frequently seen them thus run several hundred yards along a prairie track, sooner than take wing a second time. Though often seen in flocks they are not strictly gregarious, since, if disturbed, each one flies away according to individual fancy. They are eminently terrestrial in all their habits, nevertheless I have seen them feeding among the upper branches of trees in company with *Reguli* or *Dendrœcæ*. Usually they never alight on anything higher than a fence or low bush, and that only early in the morning and late at night, when they congregate in such places, and monotonously repeat a few notes which can hardly be dignified by the name of a song. Their food consists entirely of small seeds. The greater number of these sparrows leave us during March, but a few pairs certainly linger until at least the beginning of June, and I am inclined to believe, though I was unable to find a nest, that these bring out a brood in the more low and damp parts of the prairie, and then retire further north to complete the duties of the season.

Poœcetes gramineus (Gmel.) *Grass Finch.*—The grass finch arrives in this county about the last week of October, and for a short time is plentiful. Most of them, however, pass on further south, leaving but a few scattered stragglers to pass a solitary existence about the prairie fences and homesteads, where they remain until February, when they join the migratory bands then commencing to pass north. From that time until the middle of March they are found commonly about the edges of the timbered districts and the wooded creeks upon the prairie. They feed upon different seeds, among which wheat is often found, and occasionally a grasshopper or a few small insects are swallowed. The form which I obtained is intermediate between typical *gramineus* and Var. *confinis*.

Coturniculus passerinus (Wils.) *Yellow-winged Sparrow.*—This pretty little finch arrives with us about the middle of

March, and during the three succeeding months is one of the most conspicuous birds upon the prairie, frequenting the grassy slopes studded here and there with low bushes. The males have a short but not unmusical trill, which, however, resembles the chirping of an insect more than the ordinary notes of a bird, and is incessantly uttered from the top of a stunted shrub or tall weed generally, but also while in flight from one perch to another, when they take a semicircular course near the ground, gliding along with quick tremulous beats of the wings. The nest is placed upon the ground, usually on the side of a steep slope, beneath an overhanging tuft of herbage, and often so much tilted up that the eggs, which are five in number, are lying upon the side of the nest, the other side forming a half canopy over them. They are formed of dry grasses, which are often curiously interlaced with the surrounding herbage, and the sitting bird slips away so quietly that it is almost impossible to obtain it. About the end of June both young and old disappear, and, with the exception of a few straggling pairs, the great body move further north, where they, doubtless, bring forth another brood, nor do they reappear in this district in any numbers till the end of September, when they pass quickly by on the way to their winter quarters. They feed principally upon grasshoppers and coleopterous insects, but do not entirely refuse seeds.

COTURNICULUS HENSLOWI (Aud.) *Henslow's Sparrow.*—This species appears to be an autumn visitor in small numbers, arriving about the middle of October, and passing further south during the next three weeks. They are generally found among long grass, about the borders of the wooded creeks on the prairie, and when disturbed, take refuge among the branches of the neighbouring trees, in this showing a marked difference to the next species. They feed upon small seeds and insects.

COTURNICULUS LECONTEI (Aud.) *Leconte's Sparrow.*—This curious and interesting little finch, is an abundant winter visitor to the prairie, where it arrives about the second week of November, and soon becomes common in suitable localities, such as old hay fields and beds of long coarse matted grass. In such places they creep about among the stems of the herbage, never from choice rising above its top, nor unless almost trodden on do they ever take wing, and even when forced to do so, flying only a few

paces before again dropping, when they conceal themselves so skilfully, that, even upon a comparatively bare spot, it is impossible to catch sight of them; sometimes they alight upon the stem of a plant near its base, but even this is unusual, and never on any account do they perch upon a tree or bush. Their flight is wavy and irregular, and this, combined with their minute size, the rankness of the vegetation in the spots which they affect, their wonderful power of secreting themselves, and the almost impossibliity of getting a sitting shot, makes them a most difficult bird to collect. If not shot dead they flutter away among the roots of the grass, and defy all search. Though not properly gregarious they are sociable little birds, several examples being usually found in close proximity one to the other. They have a musical but rather querulous call-note, which may be heard repeatedly in their haunts though the author keeps himself quite invisible. When much disturbed they sometimes essay a more protracted flight than usual, and this is a most extraordinary performance; having risen at first about twenty feet into the air, they tumble in a slanting direction, about half way to the ground as if they had lost their balance, but recovering themselves they again rise, only to fall again, each of these efforts bringing them on about fifteen feet. Their food consists entirely of small seeds. The ear-covers of this species are ashy, not buff, as in the figure in the "History of North American Birds." The female and young show faint spots across the breast, the adult male having that part quite immaculate. As before mentioned, Lèconte's sparrow bears a distinct affinity to *Ammodromus*, even more so than it does to *Coturniculus*. These birds have all left the country by the first week of April.

Chondestes grammica (Say.) *Lark Finch.*—An abundant summer visitor to the prairie districts, arriving about the last week in March, and leaving by the end of September; they frequent the cultivated fields and mesquite flats along the border of the timber, the former principally while engaged in the duties of reproduction, the latter in small flocks or family parties towards the end of the season, when, indeed, it deserts the prairie farms in a great measure for more wooded haunts, but notwithstanding it is never found in the true timber districts Their nests are usually situated upon the ground, most frequently

in a cotton-field, and are placed on the top of a ridge, into which they are sunk so deep that the upper edge of the framework is upon a level with the surrounding earth. They are placed beneath the shelter of a tuft of grass, or among the stems of the cotton, and are formed of fine roots and grasses thickly lined with hair. I found one nest built in a mesquite about ten feet from the ground; it was a clumsy looking structure, formed of similar materials to their ordinary nests, but covered outside with loosely put-on fragments of the Texas everlasting plant. The eggs, which are usually five in number, are deposited at various times from the middle of May to the end of June. These birds are peculiarly liable to a disease of the feet, which causes the claws, and even the toes to drop off, and forms hard round lumps in their place; very few examples are free from this. Their food consists of seeds, and insects, especially grasshoppers, and not unfrequently a few green leaves are swallowed. Its song, which is continued untiringly from morning till night, is clear, vigorous, and sweet.

ZONOTRICHIA QUERULA (Nutt.) *Harris' Sparrow.*—This handsome and powerful finch is a common winter visitor, arriving about the middle of November, and frequenting thickets of green brier, and other underwood in the vicinity of taller trees, in company with *Z. albicollis*, and *Passerella iliaca.* They are tame birds, but still sufficiently wary to keep the densest growth of bushes between themselves and the intruder; but if driven from their covert they merely fly up into the branches of the overhanging trees. They are very local in their distribution, certain favoured spots being always full of them, while neighbouring brakes, apparently similar in all respects, never hold a single example. They have a quick, sharp call-note which they utter incessantly in a vexed, uneasy manner, when approached. By the end of February they have all left this district.

ZONOTRICHIA LEUCOPHRYS (Forst.) *White-crowned Sparrow.* —This species is only a migrant in our district, passing rapidly through on its periodical journeys in spring and fall. In the former they pass about the latter part of April, and beginning of May, and are then often found along fences far out on the prairie; but in fall they arrive in large numbers about the last week in October, and passing in a much more leisurely manner, remain

common for some weeks, frequenting thick brakes of tangled undergrowth in the border-land between the prairie and timber, in company with *Melospiza fasciata.* The stomachs of those examined at this season were filled with small seeds, mixed with a large amount of fine gravel.

ZONOTRICHIA ALBICOLLIS (Gmel.) *White-throated Sparrow.*—An abundant winter visitor to this section of the State, arriving in numbers about the beginning of November, and quickly spreading over the whole country, specially affecting places where dense thickets of briers and thorns cover the ground, in which they can conceal themselves, and among the branches of which they hop restlessly about on the approach of an intruder, incessantly uttering a querulous but not unmusical call-note. Heads of fallen trees, overgrown with a tangled mass of parasitic plants, are also a favourite resort; and in such places they effectually elude pursuit by running along the ground from side to side, always keeping at that which is most remote from observation; and so swiftly do they run as to make it a matter of no small difficulty to catch a winged bird; besides which, they are adepts at concealing themselves among the dead leaves. They are eminently social in all their habits, always being found in small flocks, and freely consorting with other species. When driven from their favourite haunts among the underwood, by persistent pursuit, they never fly far, but generally alight upon the nearest tree, where they hop from twig to twig in an anxious and uneasy manner. Before leaving us in March, after which month none remain, they become much more arboreal in their habits, and may then be constantly seen among the middle and upper branches of tall trees, chasing one another here and there, and keeping up a continual chatter. These birds, and indeed both of the above mentioned species also, are very partial to the neighbourhood of water. Their food in winter consists almost entirely of small seeds, but occasionally the remains of insects may be detected.

SPIZELLA DOMESTICA (Bartr.) *Chipping Sparrow.*—On the 13th November, 1880, I obtained my first and only specimen of this pretty little finch; it was feeding on the ground among dead leaves, in company with snow birds, and its stomach was filled with seeds of grass.

SPIZELLA PALLIDA (Swains.) *Clay-coloured Sparrow.*—A rare spring migrant to this district, passing northwards in small straggling bands early in May. I generally found them in low-lying mesquite flats, along the borders of the timber, and associating with *Passerculus alaudinus* and *Chondestes grammica.*

SPIZELLA PUSILLA (Wils.) *Field Sparrow.*—Very abundant wherever there is sufficient covert to shelter them, from the last week of October to March, beyond which none remain. During the winter months they are most frequently to be found on the ground among the scrubby bushes and copsewood, along the edges of the wooded creeks and timbered districts, into which latter, however, they never penetrate to any great distance, but as the season advances, they come much more up into the prairie farms, frequenting old corn and cotton fields, especially those which support a moderate growth of weeds, upon the seeds of which they principally feed, though grasshoppers and beetles are also to be found in their stomachs. They are very sociable, always feeding in flocks, and not being averse to the company of other finches.

JUNCO HYEMALIS (Linn.) *Black Snowbird.*—This form is an abundant winter visitor to the district, arriving in the beginning of November, and frequenting the borders of the woodland creeks and outlying copses, where, the ground being bare, they can the more easily seek their food of small seeds and insects among the withered leaves. Though naturally unsuspicious, they are, nevertheless, timid birds, easily frightened by an unusual noise, especially when its origin is not visible, but even when so alarmed, they never fly to a greater distance than the lower branches of the neighbouring trees and bushes, and if unmolested further, very soon return to their feeding place. They are very social, always going in flocks, and often in company with other species of similar habits. Though, as a rule, found on or near the ground, a warm, sunny winter day often entices them into the upper branches of the trees, where they hop merrily about from bough to bough, and even imitate the *Dendrœcæ* by pursuing passing insects though not always with great success. During hard weather a few may sometimes be found about the doors of prairie farms along with *Passerculus alaudinus*, but these are always young birds. They remain here until the

end of March. They roost low down in thick scrubby bushes, and even among dense weeds, near or actually on the ground.

PEUCÆA ÆSTIVALIS ILLINOËNSIS, Ridg. *Oak-wood Sparrow.*—I made the acquaintance of this sparrow only as an autumn migrant in very limited numbers, passing during the latter half of September and October. They frequent the beds of broomweed on the prairie, never, according to my observation, being found in the wooded districts, or even in the creeks, though the mesquite flats are favourite places of resort. They rarely fly, unless almost trodden on, preferring to skulk among the roots of the weeds, and even when roused, fly so short a distance that it is difficult to shoot examples without destroying the skins; my best example was knocked down with the barrel of the gun after repeated attempts to induce it to fly far enough to allow of a shot. They feed entirely upon insects, and are very greedy birds. I have found three grasshoppers, each of which was an inch long, as well as beetles, in the stomach of a single example. They very rarely alight on trees, but occasionally, when much chased, perch on the branch of a mesquite. It is likely that this species is not so rare as is supposed, but from its shy and retiring habits, it is liable to be overlooked, especially at the season in which it is found here, when it appears to be quite silent.

MELOSPIZA FASCIATA FALLAX, Baird. *Mountain Song Sparrow.*—A common winter visitor to the open districts, arriving about the middle of October and leaving again in April. They frequent the green brier brakes along the edges of the timber districts, and the patches of scrubby brush along the prairie creeks, generally going in pairs or small parties, and are, as a rule, impatient of observation, showing, when approached, great restlessness, and continually uttering a low querulous cry indicative of uneasiness. They feed principally upon the seeds of various grasses and weeds, but do not refuse small insects also. They rarely rise into the branches of trees, but prefer to keep low down among the stems, or upon the ground beneath the bushes which they haunt.

MELOSPIZA LINCOLNI (Aud.) *Lincoln's Finch.*—This handsome little sparrow is a migrant in this district, passing north in large numbers from the middle of March to that of May, and frequenting at this time the wooded creeks and borders of the timber

lands, especially in the neighbourhood of water. They are generally found in pairs, resorting to thick clumps of low bushes and the tops of fallen trees, the latter being almost a certain find, and are not easily obtained, as they lie hidden among dead leaves and rubbish on the ground beneath such places, and do not stir as long as the intruder remains in the vicinity of their hiding place. In April it was the most abundant bird in the creeks. They feed indiscriminately on seeds and insects. They pass again on their return journey during October, but in much smaller numbers than during the spring migration, and at this season appear to keep more to the bottom lands, perhaps because of the absence of water in the creeks. Not even at this time are they in the slightest degree gregarious, but, on the contrary, show great aversion to the near presence of any of their own species.

PASSERELLA ILIACA (Merrem.) *Fox-coloured Sparrow.*—This powerful species is a common winter visitor to the wooded creeks which intersect the prairies, frequenting spots where an undergrowth of briers and vines springs up around the roots of loftier trees. They arrive with us about the middle of November in small flocks, which, however, soon break up; and, during the remainder of their stay, which lasts until the end of February, they are most frequently seen singly or in pairs. This, however, arises from no want of sociability, since they are always found in company with *Zonotrichiæ,* which they resemble in many of their habits. Like them, when driven from their briery strongholds, they merely take refuge among the middle branches of the trees overhead, where they consider themselves quite safe from harm. Though so eminently a woodland bird, it is never found in the dense timber of the river bottom, but only on the outskirts and in the narrow creeks. Their food consists both of seeds and insects, and sometimes also of small shells.

PIPILO ERYTHROPHTHALMUS (Linn.) *Towhee.*—This fine finch, which resembles the last-mentioned species in many ways, is also a common visitor, arriving early in November, and leaving again by the end of March. They are very terrestrial in their habits, frequenting dense thickets of underbush, among the leaves beneath which they scratch for food in the manner of gallinaceous birds. It is rare to find more than three or four of these birds in the same thicket, except perhaps on their first arrival, previous to

the breaking up of the family parties. Before the spring migration there does not seem to be even this slight community. Their food consists entirely of seeds, and their stomachs, therefore, always contain a large quantity of gravel.

CARDINALIS VIRGINIANUS (Briss.) *Cardinal Grosbeak.*—The redbird is abundant in this district at all times of the year, frequenting the thickly timbered lands along the banks of the river and its tributary creeks, and even the outlying copses upon the prairie, showing always a decided partiality for the neighbourhood of water Though resident here and equally common in winter as in summer, the migratory impulse affects the young at least during the fall, and they may frequently be met with then along the fences of prairie farms, remote from any covert. Those, however, which are bred in this county remain here, and the young keep with their parents during the winter in some thicket in the neighbourhood of their birthplace, except indeed when that happens to be in an exposed and isolated position, which is thereupon deserted for the more sheltered brakes of the woodlands; but, on the approach of spring, the old birds, who remain mated during life, return to their former nesting place. They are very vivacious birds, ever on the move among the branches or pursuing one another from tree to tree, and they are always the first to sound the alarm on the approach of an intruder to their haunts, whom they follow pertinaciously wherever he goes, incessantly uttering their warning cries, which are well understood by all the members of the feathered race in the neighbourhood. Their song, which is sweet and pleasing, and is given with equal power and volume by the female as well as the male, is continued almost incessantly during the greater part of the year. The nest is placed in a thick bush or in the vines clinging round the trunk of a tree, and is formed of bits of twigs, coarse weeds and dead leaves, lined with grass and fine roots; the usual number of eggs is five, and two broods are produced in the season. The young are fed entirely on soft grubs and caterpillars, but the parents consume quantities of seeds and corn in addition to these. While engaged in incubation, the birds keep more quiet than at any other time, slipping silently away when the nest is approached, though keeping a sharp lookout all the while; but, when the nest is discovered, they lose all fear and flutter around the intruder with

heartrending cries. They are more infested with small ticks than any other of our resident species.

GUIRACA CÆRULEA (Linn.) *Blue Grosbeak.*—The blue grosbeak, nowhere a common bird in our district, is a summer visitor, arriving about the middle of April, when it may often be found along the fences of prairie farms, and leaving us during August. They resort in summer to outlying copses and the terminations of wooded creeks, and build their nests on thick bushes from four to six feet above the ground; these are placed in a fork of the main stem, upon a basis of withered leaves and wool, the side being formed of coarse grass and weeds, and the interior thickly lined with fine roots; they are ingeniously fastened to the supporting boughs by the wool, which is always present. During the fall they resort to beds of tall weeds on neglected farms, and feed greedily on the seeds of the sunflower, knot grass, and other noxious plants.

PASSERINA AMŒNA (Say). *Lazuli Bunting.*—I obtained a bird on September 17th, which, on account of the faint indications of bands upon the wings, I considered to belong to the above species. It was a young male—a wretched specimen—with the feathers much abraded and dirty.

PASSERINA CIRIS (Linn.) *Painted Bunting.*—This active and pleasing little finch is an abundant summer visitor to all the prairie districts, where it makes its appearance during the last week of April, the males preceding their partners by a few days; they quickly become a conspicuous object from their gay colours and sprightly song, which is poured forth perseveringly, from the first glimpse of dawn to long after sunset, from the summit of a low bush, weed, or stake in a fence. They commence to nest immediately on the arrival of the females, and the full complement of five eggs is often deposited by the third week of May. The nests are placed in a low bush or weed, about three or four feet from the ground, and are always lined with hair; one built in a sunflower but a few yards from the house door was formed of weeds and cotton plaited carefully together, and was laid on a basis of withered leaves and pieces of newspaper. Fragments of the cast skins of snakes are frequently interlaced with the fabric. They breed twice in the season, the young of the first brood being tended by the male, while his mate is incubating the second. As

the male is frequently found breeding while still clad in the sober garb of the young bird, it is probable that it does not don the brilliant colours of the adult state until the second moult. They are quite indiscriminate in their choice of food, swallowing with equal relish all kinds of seeds and insects which they can manage. The nestlings, however, are fed altogether on soft insects. None of them remain in this neighbourhood after the middle of September, and, indeed, by the end of August, all except stragglers are gone. They frequent clumps of bushes and weed beds upon the prairie, and the brushwood along the edge of the timber, and wooded creeks, but are never found in the deep bottom lands. The only egg of a cowbird which I obtained was deposited in a nest of this species before any of those of the rightful owner were laid; upon which a new nest was immediately built within a few feet of the former one, and five eggs safely hatched out. These birds and *Vireo belli* have their nests destroyed by prowling animals more often than the ground-breeding species, whence it may be inferred that sight is used more than scent in the pursuit, the position of these nests being very conspicuous to any animal passing beneath them.

Spiza americana (Gmel.) *Black-throated Bunting.*—An abundant summer visitor to the open districts, arriving about the middle of April and leaving early in September. They frequent the low-lying parts of the prairie, especially where stunted bushes are scattered about, and farms on which bad cultivation allows large areas to become overgrown with weeds. From the time of their first arrival up to the end of June, their monotonous song may be heard every hour of the day, poured forth from the top of a bush, weed, or fence, with most untiring diligence, even when the heat of the midday sun has silenced all other songsters. They bring forth two broods in a season, laying four or five eggs in each clutch, the first being ready for incubation by the middle of May. The nests are built either on a low bush or weed, never more than four feet from the ground, or on the ground beneath a tuft of grass on the prairie, the bases being formed of withered leaves, on which is raised a superstructure of dry grass and weeds firmly interlaced, the whole being warmly lined with fine roots. As soon as the second brood is able to fly, they band together in large flocks, resorting to the beds of sunflowers and bloodweeds,

where they do good service by consuming the seeds of these and many other noxious weeds, notably those of the knot grass. During the summer they feed almost exclusively on grasshoppers and other insects.

MOLOTHRUS ATER (Bodd.) *Cow Bird.*—This curious species, in which the parental instinct, so strong in most birds, seems to be entirely undeveloped, is found in our district at all seasons of the year, but is infinitely more numerous during the colder months; in fact, they are quite scarce in summer, at which time they move about in small flocks, frequenting open glades and roads in thinly wooded localities; but, when about to lay, the female separates herself from the flock and seeks for a suitable nest in which to deposit her egg, rejoining the flock when this is accomplished. Early in September they begin to appear in flocks in the open districts, the female and young preceding their mates by some days, but, after the arrival of the latter, the different bands unite to form mixed flocks of almost incredible numbers; and during the whole of the winter, every herd of cattle has its accompanying flock, the members of which run fearlessly about among their feet, eagerly picking up the insects roused by their trampling, or attracted by their bodies, and alighting often in numbers on their backs, where they pick off the ticks with which they are infested, thus, at the same time, ministering to their own wants and to the comfort of the cattle. In hard weather they sometimes take shelter in the dense timber along the rivers, feeding on the berries of the cedar and green brier. The only egg which I found, was laid in a nest of *Passerina ciris* before any of the eggs of the finch had been deposited, and the nest was at once deserted.

XANTHOCEPHALUS ICTEROCEPHALUS (Bonap.) *Yellow-headed Blackbird.*—A spring migrant in small numbers, passing northward in company with cowbirds and grakles, during the latter half of April and beginning of May. They frequent large farms on the prairie and places where the ground is bare, such as the neighbourhood of villages, where the grass has been worn away, and it is rare to see more than three or four in the same place. The stomachs of those which I examined were crammed with grasshoppers.

AGELÆUS PHŒNICEUS (Linn.) *Red and Buff-shouldered Blackbird.*—The red-winged starling is one of the most abundant birds

in the open districts during the winter months, where it arrives in small flocks about the latter half of September. The migrations of the sexes are performed separately, the females arriving some time before the males in the fall, but in spring the order is reversed, large flocks of females remaining after all the males have disappeared. Meanwhile, however, the different flocks unite in certain favoured places, especially at night, when particular spots, such as large beds of tall weeds, old corn fields, and isolated coppices are resorted to for the purpose of roosting, and to these places the birds may be seen coming in flocks about sunset from their feeding grounds in the neighbourhood. These companies do not alight on their arrival at the roosting place, but continue circling round and round above, each fresh band joining those which have arrived previously, until the air is black with them, still the organization is so complete that a great number of birds take up a comparatively small space. For some time they continue thus, carrying on all the while most beautiful aërial evolutions with marvellous unanimity, now wheeling to one side, now sweeping down like a living cataract till they almost touch the weeds, and again rising into the air to repeat the movements, but all the time acting as if but one impulse swayed the whole host. Large areas of weeds may often be found broken short off by the weight of the birds overcrowding to roost on them. About the beginning of April the main body move north to more suitable breeding haunts, leaving but a few scattered pairs, which still linger in favoured places, such as the weed-covered margins of creeks which have not yet quite dried up after the winter rains. Here they bring out one brood during May, the young of which I have shot when only just able to fly early in June, but by the middle of that month they disappear entirely from the district, probably passing further north in search of better watered lands, the prairie creeks having become dry by that time. Although these birds, doubtless, do considerable damage to the newly-sown corn and wheat, it must be remembered that for the greater part of the year they perform invaluable service to the farmer by the destruction of myriads of noxious insects, and at no time are they more useful than during farming operations, when they follow the plough in large numbers, greedily devouring the grubs and larvæ which are turned up; they also con-

sume the seeds of many plants which would otherwise choke the ground.

STURNELLA MAGNA (Linn.) *Meadow Lark.*—The eastern form of the meadow lark is only found in this county during the winter months, when it is spread over the whole district in large numbers. They arrive about the end of October, in flocks of from fifty to one hundred, and even more, individuals; the severity of the weather further north is, however, the main cause which regulates their arrival, and even after Christmas fresh accessions are made to the numbers of our visitors with any increase of cold. After their arrival the flocks break up for the most part into small parties, which frequent the corn and cotton fields upon the prairie, and in the thinly wooded districts, and even in the cleared farms of the river bottom, where the allied forms are never found; here they feed upon beetles, grasshoppers, spiders, and in fact every variety of insect food then obtainable, along with corn and various seeds. These birds leave us again about the end of February, none remaining to breed with us. Though naturally a timid bird, they become comparatively tame during the cold months, and resort to the neighbourhood of houses and farmyards, associating and feeding fearlessly among the domestic poultry, but, if molested, as sometimes happens because of the excellence of their flesh, they become so wary as to make it a matter of no little difficulty to approach them. They continue in song during the winter, no matter how rigorous the weather may be, perched upon a stake in the fence, a tree, bush, or tuft of grass, and even the housetop, their notes being sweet and clear, but sadly deficient in compass and volume. They are, however, pleasant to hear at that season, when songsters are scarce upon the prairie.

VAR. MEXICANA (Sclat.) *Mexican Meadow Lark.*—This form, which differs from *S. magna* in its smaller size, but longer tarsi, and in the much greater amount of black on the back, rump, and tail feathers, replaces the eastern species in summer, arriving about the end of March, and leaving us during September. They frequent only the grass lands of the prairie and hayfields upon the farms, and are much more unsociable than their congeners, never resorting to the neighbourhood of houses. They seem to feed entirely upon grasshoppers, which they catch by running them

down, putting the same insect up again and again until they tire it out; they pluck the wings off before swallowing their prey. Their ordinary mode of progression is a slow walk, but when pursuing their insect food, or getting out of the way of an approaching person, they are capable of running swiftly. They are poor fliers, scarcely seeming to be able to make headway against even a moderate breeze, and invariably flying down wind by choice. Before leaving us in the fall, the families keep together in small flocks, sheltering themselves during the heat of the day among the foliage of trees or among long grass and weeds. They sometimes sing while flying, but generally from the summit of a low bush or tuft of grass, and their notes are much less musical than those of their earlier representative. In spring, while mating, these birds may be watched going through most extraordinary manœuvres; taking up a position on a bare spot of ground, a pair will stand about two feet apart, and for several minutes at a time bow to one another with ludicrous solemnity, occasionally varying the performance by short leaps into the air. The nests are placed upon the ground, on the slope of a hill, and beneath a tuft of long grass, which is carefully bent and woven over it, so as to form a roof, and are large, untidy structures of withered grass. Two broods at least are brought out, and the eggs, which number four or five, vary greatly in size and markings.

STURNELLA NEGLECTA, Aud. *Western Meadow Lark.*—This species, never so abundant as the forms of its congener, is resident in the district, but is more often met with in winter than in summer. They are less shy than *S. mexicana*, and even in summer do not desert the neighbourhood of prairie homesteads, frequently breeding in close proximity to houses. Their song is much more varied and powerful than that of the other species, and cannot be mistaken for it; and their flight is also stronger, the beats of the wings being much more continuous. They have a curious habit, when flying away, of turning the head round from side to side to look behind them. I found but one nest of this species, which was built differently to those of the other larks, being among short grass, perfectly open, without any attempt at covering; the male was sitting upon three eggs. During the winter they consort with parties of *S. magna* about the prairie

fields, feeding like them on seeds and insects. The different forms of *Sturnella* are more often found dead beneath the telegraph wires than any other species.

ICTERUS SPURIUS (Linn.) *Orchard Oriole.*—One of the most abundant of the summer visitors to the prairie, on which they arrive about the middle of April, the males preceding their partners by a week or ten days. They quickly spread themselves over the county, frequenting only the open districts, and during their stay they are especially common on the prairie farms containing peach orchards, and in all places diversified by scattered coppices, or isolated mesquite and locusts. Immediately after the arrival of the females, they commence their seasonal duties, and by the third week of May the eggs of the first brood are in process of incubation. In this duty the males perform no mean part, not only taking their turn on the eggs, but even feeding their mates while sitting, so that when the incessancy of their song is taken into consideration, very little time appears to be left for attending to their own wants. The nests are placed most commonly on peach trees or mesquites, the lowest or the highest branches being indifferently chosen, and though never breeding, strictly speaking, in societies, several inhabited nests are often built within a small area, while upon the open prairie, where suitable sites are scarce, it is no unusual thing to find two on the same tree along with those of the scissor-tail and mocking-bird, the parents living together with perfect unanimity. The nests are always placed near the extremity of a branch, with no attempt at concealment, and are pensile, the upper edge being carefully fastened to several small twigs which are interlaced back and forwards with the fabric. The materials used are long, fine dry grasses neatly woven together, and occasionally a few feathers are added by way of a lining; more often, however, there is no special lining. Sometimes these nests are so thin that the eggs may be seen through the bottom, but they are at all times so strong that they resist even severe winter storms without losing shape. A second brood is produced in July, the male meanwhile, in addition to his other arduous duties, feeding and watching over the safety of the first clutch. By the end of August most of these birds have left, but a few, chiefly females and young, linger for a fortnight after that date. The males do not attain the adult

plumage until their fourth year, but they breed in the immature plumage of the second and third seasons. Their food consists entirely of insects, many of which are most harmful to the farmer and gardener, notwithstanding which they are frequently classed with other species under the general title of "wheat birds," and their nests, when built in orchards, ruthlessly and foolishly destroyed. I have heard the females called "Mexican canaries."

Icterus galbula (Linn.) *Baltimore Oriole.*—This beautiful bird appears to be very rare in our district, but one example, an adult male, having come under my notice during my stay in Texas. I obtained this specimen in an old orchard upon a clearing in the river bottom, on the 30th August, 1879. Its stomach was filled with small caterpillars and grubs.

Scolecophagus cyanocephalus (Wagl.) *Brewer's Blackbird.*—A common winter visitor to the open districts, frequenting the neighbourhood of houses, especially such as have large yards and hogpens attached, where they feed upon the insects which congregate in such places, frequently even alighting upon the hogs for the purpose of picking off infesting parasites, a proceeding which evidently meets with the full approbation of each animal. They arrive here early in November, and roam in an unsettled way over the whole country, going in small flocks and exhibiting a restless, uneasy disposition. They are active, sprightly birds, generally on the move, and, though eager in the search for food, so restless that they cannot remain on the ground for five minutes at a time, but continually rise as if frightened, though perhaps only to fly a dozen yards. They are more exclusive in their habits than any of the other blackbirds, so that it is rare to find them associated with other species. They leave this district early in March.

Quiscalus purpureus (Bartr.) *Purple Grackle.*—This grackle is a common summer visitor to the county, where it arrives about the middle of March, and, being of a sociable disposition, principally affects thinly wooded localities in the neighbourhood of towns, villages, and large farms with sheep and hogpens attached, but it is rare to see any in uncultivated and uninhabited districts. They bring out but one brood in the season, the young of which are able to fly by June, and from that time until their departure

in September, they band together in small flocks of from ten to thirty individuals, and rove about the country in search of food, returning every evening to some prairie tank to drink and bathe. Though accused of doing injury to the standing corn, I have never found any remains in the stomachs of many specimens to lead me to that conclusion, but, on the contrary, insects of many kinds—beetles, grasshoppers, wasps, caterpillars, grubs, and the larvæ which so frequently prove injurious to the growing corn, were by examination proved to be consumed in enormous numbers.

VAR. ŒNEUS, Ridg. *Bronzed Grackle.*—Upon the 9th November, 1880, six weeks after the ordinary date of the departure of the species, I met with a flock of grackles, an adult male of which having been obtained, proved to belong to this form. The irides were of a markedly brighter yellow than those of our common summer variety.

CORVUS FRUGIVORUS, Bartr. *Common Crow.*—This crow is a constant resident in our district, frequenting in summer the dense timber of the bottom lands, where it makes its nest among the upper branches of lofty trees in the immediate neighbourhood of water, but at other seasons resorting to the thinly-wooded lands on the skirts of the prairie, whence they issue daily far out upon the open country in search of food, returning each evening to the same roosting place. At this time they are more or less gregarious, flocks numbering as many as an hundred individuals being by no means uncommon, but I am inclined to think that the greater number, if not all, of these bodies are of extraneous origin, since a sufficient number of small family parties may always be met with in the same districts to account for the native-bred population. That indeed we receive large migratory bands of crows during the early part of the winter is certain, since on the 26th November I witnessed the passage of a flock consisting of quite a thousand examples; they were flying steadily in a south-westerly direction, at a great height, and since the papers of the previous days had mentioned heavy snowstorms in more northern states, it is probable that these birds had come from the snowed-up regions. Crows frequently do much damage to the corn crop, both when it is beginning to sprout, and also

when it is ripe; in the latter case they pull off the outer leafy covering of the grain, and after picking off a few of the seeds from the cob, pass on to another plant, thus wasting far more than they consume by leaving all exposed to the weather and to the depredations of more secret enemies. They are excessively wary, rarely allowing of an approach within gunshot except by a person riding. In addition to grain, it is but fair to state that they also consume large quantities of insects in their various stages, and in winter feed on acorns, cedar berries, grapes and other large seeds.

Cyanocitta cristata (Linn.) *Blue Jay.*—Common and resident at all seasons of the year, though doubtless receiving considerable accessions to its numbers during the fall, at which time, and in the winter, they may be met with in small flocks in the sparsely timbered districts bordering the prairie; whereas in the breeding season they are unsociable among themselves, and seek a nesting place among the most unfrequented recesses of the river bottom. They feed in summer entirely upon insects, both in their larval and perfect forms, but in winter consume corn and various other seeds and berries, among which acorns are most common; the kernel of these they obtain by placing the acorn lengthwise along a branch, choosing always a rough-barked tree, and holding it firmly in its place with one foot, between the toes of which they give quick repeated blows with the closed bill until they succeed in breaking the epidermal portion of the fruit. Though not molested in any way, they are with us shy and suspicious, and would not be easily obtained but for their uncontrollable curiosity; in winter, however, I have sometimes found them very tame, but these may have been immigrant individuals. The form which is resident here seems to be smaller than the eastern race, rarely exceeding 11·50 inches in total length: these specimens were measured in summer only.

Eremophila alpestris (Forst.) *Shore Lark.*—An abundant winter visitor to the prairie districts, where it arrives about the last week of October, the females and young making their appearance in small flocks quite a month before the males, and these latter again leave during February, and though followed

early in March by the main body of their partners, straggling bands of females may be observed up to the middle of the succeeding month. During the greater part of their stay they frequent the cotton fields and bare sandy parts of the prairie in company, with the different species of *Plectrophanes,* but though feeding along with them, keep separate in flight; in severe weather they resort to the neighbourhood of barns and dwelling-houses, and may even be seen searching for food in the streets of the larger towns. I never saw these birds alight upon trees, but they perch very commonly upon rail fences; they pass the night on the ground, squatting in the wagon-tracks and hoof-marks on roads crossing the higher parts of the prairie. The call-note is a clear musical whistle, and is uttered both at rest and in flight, having, when a number of birds are present, a very pleasing effect. The food of the shore lark consists of small insects and seeds which are always more or less intermixed with coarse gravel. The race separated by Dr. Coues as *Otocorys leucolæma* is equally common here with its eastern representative and is the earlier of the two to arrive and the later to depart, for which reason we may infer that it does not migrate so far in search of summer quarters. When both forms are here they mix together in the same flock, nor is there the slightest difference in habits or note.

MILVULUS FORFICATUS, (Gmel.) *Scissor-tail.*—The Bird of Paradise, as this beautiful fly-catcher is called in Texas, is an abundant visitor to our district, where it frequents the open lands, and forms an eminently characteristic feature of prairie life. They begin to arrive about the latter end of March and though migrating singly or in pairs, show an inclination to gather into small flocks on their arrival: they are at all times social birds, fond of the company of their own species, and though from the nature of their breeding places, they are forced to scatter during the periods of incubation, they quickly resume their gregarious habits upon the completion of those duties. Nearly every isolated tree upon the prairie bears at least one nest, which is generally, but not always placed at some distance from the main stem, and is loosely constructed of roots, grass, cotton, and other substances, among which the Texas everlasting plant is invariably present. The eggs are four or five in number, and two broods are produced during the

season. As soon as the second brood becomes strong enough on the wing, the different families leave the more open parts of the prairie and betake themselves to some suitable clump of trees in the neighbourhood where they pass the night, making daily excursions to the surrounding country in search of food. In such places several hundred will collect nightly, and before retiring to roost occupy some time in desultory flights, pursuing one another hither and thither, and frequently ascending to a great elevation, from whence they return by a rapid and headlong rush, accompanied by a peculiar whirring noise made by their wings, which can be heard at a considerable distance. They are excessively graceful in all their motions, and their flight is lighter and more buoyant than any other bird with which I am acquainted. Their food consists of bees, moths, beetles, small grasshoppers and other insects, all of which are caught in the air. Although their ordinary note is harsh, even during the breeding season, they have a habit during the fall of singing in concert, most frequently before retiring to rest, with a clear musical, but faint warble, which is very pleasing, when, as is usual, a large number are engaged at the same time; and these notes are not confined to the males, but females and young seem likewise to participate in this evening hymn. They fearlessly attack any predatory birds, such as hawks, and crows, which may venture into their haunts, and not content with showing their dissatisfaction by angry cries alone, use their beaks also with such effect that the marauder is quickly put to flight. The greater number leave this district during September, but small straggling flocks, composed entirely of adult males, linger in sheltered localities until the end of the following month. The stomach of a specimen obtained in the fall contained grapes and snowberries, but this was the only instance in which I found traces of vegetable food.

TYRANNUS CAROLINENSIS (Linn.) *King-bird.*—A common summer visitor to the thinly wooded portions of the county, arriving about the middle of April; mesquite flats along the edges of the denser timber, and wooded creeks, are the favoured haunts of this bird, especially where a few large isolated trees are interspersed at intervals, their nests being very frequently placed among the upper branches of these. In the spring they arrive always

either singly or in very small parties, but in fall they collect together in large bands before and during migration. During the last week of September such a flock, computed to consist of at least a thousand individuals, arrived at the farm ; they came from a north-easterly direction in a long straggling body, and settled in the corn field, and were so tired that they would hardly flutter away to the nearest unoccupied stalk upon being approached. This happened late in the evening and by sunrise next morning all had disappeared. It is rare to see any after the first week of October. Occasionally they may be observed hawking for insects in company with swallows, and even attempting to pick them from the surface of a prairie tank like those birds, beside whom however their movements were very awkward, for while the swallow would gracefully capture the insect and scarce leave a ripple behind it, the bee martin more frequently made a considerable splash.

MYIARCHUS CRINITUS (Linn.) *Great-crested Flycatcher.*—An abundant summer visitor, arriving early in May, and frequenting the open woods and creeks. The nests are placed in old borings of woodpeckers, and are formed of a variety of substances, such as wool, cotton, hair, grass, and feathers piled up to the depth of several inches on the bottom of the hole, and the cast skin of a snake is always found interlaced with the other materials; five seems to be the usual complement of eggs, but occasionally six are deposited, and two broods are produced, the young of the first leaving the nest before the end of June. They feed the nestlings entirely upon insects, chiefly small grasshoppers, bees, and beetles, but seeds and berries appear to form the main part of their food during the fall. They are at all seasons unsociable, evincing a decided distaste for the proximity of other birds, whether of their own species or not. They do not remain here after the middle of September.

SAYORNIS FUSCUS (Gmel.) *Pewee.*—Though for the most part merely a migrant through our district, a few pass the winter in sheltered localities, such as the thinly-wooded lands along the outskirts of the river bottom, and the edges of glades and clearances in the timber, but they all pass north before the end of March, during which month they are very plentiful everywhere. They begin to appear again about the middle of August, and from that

time until the end of October are numerous, especially frequenting mesquite flats and post-oak woods; where they may be seen at all hours, generally seated upon the highest shoot of a small bush, but occasionally upon the summit of a dead tree, whence they launch forth in pursuit of passing insects, which they catch with great adroitness, and seldom returning to the same perch. They usually go in pairs, but sometimes as many as a dozen may be observed about the same tree. They consume considerable numbers of caterpillars and grubs in addition to the winged insects, and in the fall at least feed very commonly on grapes and various other seeds and berries.

Contopus borealis (Swains.) *Olive-sided Flycatcher.*—This fine species is not uncommon during the fall, being found about the edges of clearings and open glades in the river bottom. They are solitary in their habits, at once resenting the encroachment of any member of their own species which may venture into the neighbourhood of their haunt, which consists always of some tall dead tree, on the very summit of which they take their stand and pursue, sometimes for quite a long distance, the passing insects, always returning to the same perch. I never saw any after the first week of October, although I particularly looked for them, nor did I observe them in the spring.

Contopus virens (Linn.) *Wood Pewee.*—A common summer visitor, frequenting tall open woods in the timber districts during the breeding season. They begin to arrive early in May, and at that time are abundant in the mesquite flats bordering prairie creeks, and even along fences remote from any trees, (in such places too they may not unfrequently be observed on the return migration in the fall), but never linger long in such spots, and with the advance of summer retire to the shady recesses of the timber. They do not remain here after the end of September; their migrations are performed in pairs or singly at all seasons. They feed entirely on winged insects; wasps, beetles, and flies being most commonly present.

Empidonax flaviventris, Baird. *Yellow-bellied Flycatcher.*—A summer visitor in limited numbers, frequenting the open woods, creeks, and isolated clumps of trees and bushes upon the prairie. They arrive about the middle of May, but are never common and, being silent and shy, escape observation during the critical period

of incubation, but during the fall they appear more frequently about the edges of the timber, generally in pairs, though small family parties occasionally occur ; and in sheltered glades individuals linger up to the middle of October, but the greater number leave a month previous to that date.

EMPIDONAX ACADICUS (Gmel.) *Acadian Flycatcher.*—I met with this species only during August and September, when it may be found in considerable numbers along the outskirts of the woodlands, about the edges of clearings in the timber, and even in small patches of bushes upon the prairie, always choosing places where there are low scattered shrubs, on which they rest in preference to more lofty trees ; but wherever they may be they are shy and restless under observation, flitting ceaselessly about from branch to branch, and frequently uttering a sharp complaining note. Their food consists generally of minute insects, with which a few seeds are often mingled.

EMPIDONAX PUSILLUS TRAILLI (Aud.) *Traill's Flycatcher.*—A common summer visitor to the deepest recesses of the low-lying districts along the banks of the Trinity River, and its tributary creeks, where its shy and retiring habits cause it to be easily overlooked unless special search be made for it. I usually observed this form in places where there was a considerable growth of underwood, upon which they perched sooner than on more elevated resting-places. They are more plentiful and more familiar in the fall than during the breeding-season.

EMPIDONAX MINIMUS, Baird. *Least Flycatcher.*—This is much the rarest species of *Empidonax* in our district, and is only an autumn migrant, occurring occasionally about the edges of creeks and detached brakes during August and September. The stomachs of both my specimens were crammed with minute coleoptera.

TROCHILUS COLUBRIS, Linn. *Ruby-throated Hummingbird.*—An abundant summer visitor to suitable localities, arriving about the beginning of May, and chiefly frequenting orchards and open glades in the low-lying timber districts; they are quite unsuspicious, carrying on their pursuits within a few feet of the observer and habitually resorting to even small garden patches beside busy thoroughfares of towns. They are specially numerous about open places in the vicinity of water. During the last week of August I first observed them passing southward on migration, and from that

date until the end of September they continued to pass in considerable numbers whenever the weather was fine. Their flight at this time was swift, steady, and protracted, at a height of about twenty feet from the prairie, which they followed in all its undulations; occasionally however one would shoot up into the air, but almost immediately descend to the original level. Some idea of the magnitude of this migration may be formed when I say that I have frequently counted a score pass a given spot in a few minutes, and all singly, for it is very rare to see even two together. During the greater part of this time the wind was due south, but for a few days it came from the opposite quarter with rain and gloomy weather, and the migration totally ceased during its continuance.

CHÆTURA, sp. (?)—I saw swifts several times during the autumns of 1879–80 hawking above the river, but they always kept at so great a height that I was unable to get a specimen; they never uttered a sound that I could hear, and for these reasons Mr. Ridgway thinks it probable that they may have belonged to the western form, *C. vauxi.*

ANTROSTOMUS CAROLINENSIS (Gmel.) *Chuck-Will's-Widow.*—This species, which is generally called "Whip-Poor-Will" here, is a common summer visitor to the county, frequenting the woodlands, where its monotonous cry of "Chuck ——widow-the-widow" may be heard incessantly every evening from shortly before sunset until about an hour after, when it ceases for that night. They arrive during April, and remain with us to the middle of September, but are rarely heard calling after June. I never could see one during the day-time, which they are said to pass in hollow trees, but they continue feeding all through the night, at least when there is bright moonlight. Their cry is uttered from the upper branches of a dead tree, never while in flight; and their food consists of large moths and beetles.

PHALÆNOPTILUS NUTTALLI (Aud.) *Poor-Will.*—This is a scarce summer visitor, frequenting the very densest thickets of the river bottom, where they are very hard to obtain, as well from the nature of the localities which they haunt, as that they crouch upon the ground among dead leaves and fragments of rotten wood, to which materials their colours assimilate so closely that it is quite impossible for the eye to distinguish them. They lie during the day-time until almost trodden on, and even when roused again and

again rarely fly more than a few yards. When migrating during September and October, they sometimes occur in the narrow wooded creeks far out on the prairie.

CHORDEILES POPETUE (Vieill.) *Night-hawk.*—A very abundant summer visitor, frequenting the most open prairie districts, and thinly-wooded localities during the breeding season, but in fall resorting greatly to the post-oak barrens, where they pass the greater part of the day, crouched along the upper branches of the trees. They feed principally in the early morning and late evening, but suffer no inconvenience from the sunlight, as they may be seen occasionally pursuing insects in the broad glare of day; unlike *Antrostomus* they never hunt during the night. They arrive with us about the last week of April, and immediately set about the duties of incubation. They form no nest, depositing the two eggs in a slight depression of the soil, bare patches of sand upon the open prairie being a very favourite site; when the nest is approached, the female employs all her art to decoy the intruder from its neigbourhood. By the end of September they have all left this district, and during that month migratory bands may often be seen passing; they fly high and steadily in a south-easterly direction in a long straggling flock, so that I have watched them pass in this way for an hour at a time. The white alar patch is very variable in size, and cannot be taken as a reliable specific character. Only the typical form is found here.

PICUS VILLOSUS (Linn.) *Hairy Woodpecker.*—A scarce resident in the wooded districts of the county, and much more frequently met with in winter than in summer. During the latter season I only observed it once or twice in unfrequented parts of the timber districts, where it was very shy and suspicious, but in the colder months they come out into the more open woodlands and prairie creeks, and are comparatively tame. The specimens which I obtained differed from typical *villosus* only in the colour of the frontal feathers, which were brown and not white.

PICUS PUBESCENS, Linn. *Downy Woodpecker.*—A resident in our district, but far less common in summer than in winter, when it is abundant everywhere in the woodlands and creeks; it is most emphatically a migratory species, and during the fall numbers may be seen almost every day accompanying the flocks of warblers, creepers, titmice, and kinglets, in their passage south, while the

same companionship may also be observed in spring though not in so marked a manner. Both male and female assist in the excavation of a nest-hole, the work being commenced early in April; two broods are produced in the season. During the summer insects in their various stages are most commonly used as food, but various ripe berries and seeds are preferred in autumn and winter.

Picus scalaris, Wagl. *Texan Woodpecker.*—This species, which might suitably be called the prairie woodpecker, is common and resident, but more abundant in summer than in winter. They are never found in the dense timber, but frequent isolated trees and coppices upon the prairie, breeding at all heights, from the upper branches of tall trees to low half-rotten stumps within six feet of the ground, and even where the country is very open, making excavations in the upright posts of fences. They are tame and fearless and will continue their search for food unmindful of the near presence of an observer; several may often be seen together, especially on an old fence, where they obtain a rich harvest from the concealed insects and larvæ therein, and are thus of great use in assisting to preserve the wood from their insidious attacks; during the autumn and winter they feed on berries and seeds to a considerable extent.

Sphyrapicus varius (Linn.) *Yellow-bellied Woodpecker.*—A winter visitor in small numbers, arriving about the beginning of November, and frequenting both the dense woodlands and the prairie creeks; it is generally solitary but sometimes a pair may be observed together. With the exception of the usual drumming noise, I never heard this woodpecker make any sound. Their habits are similar to those of *Picus pubescens*, but they are much more intolerant of observation, and seem to feed more on vegetable products than that species, but this may not be the case in summer.

Hylotomus pileatus (Linn.) *Log-cock.*—The wood-chuck is abundant and resident throughout our district, frequenting in summer only the densest and most solitary recesses of the river bottom, among which its loud screaming laugh may be heard at all hours of the day: it is the most wary of all our birds, always on the lookout for danger, and suspicious of any unwonted sound; they are especially common in the neighbourhood of water. During the winter they are often found in the post-oak woods,

and sometimes in the narrow belts of timber upon the prairie, but even then nothing can exceed their watchfulness. The few nests which I saw were placed at a great height in tall old cotton woods, generally overhanging water, and quite unattainable.

CENTURUS CAROLINUS (Linn.) *Red-bellied Woodpecker.*—This is undoubtedly the most abundant of our sap-suckers, and is resident, though like the other members of its family, less often seen during the breeding season, owing to their retirement in great measure to the denser woodlands at that time, while in the colder months they appear commonly in the creeks and scattered coppices upon the prairie; sometimes however they form their nests remote from any trees, as in a post supporting the corner of an outhouse upon a prairie farm. They seem to pair for life since even in the depth of winter two are generally found together. Their note is a shrill disagreeable scream which may be heard ringing incessantly from the woods, at all hours of the day, and seasons of the year. During the spring and summer months they feed entirely upon insects, grubs and caterpillars, but in the fall and winter they consume quantities of seed and berries, and are especially partial to the wild grapes.

MELANERPES ERYTHROCEPHALUS (Linn.) *Red-headed Woodpecker.*—By no means a common bird in our district, to which it appears to be mainly, if not entirely, a summer visitor, at least I never observed it except from April to September inclusive; and even then much more often during the fall than at other times. They frequent open woods and clearings in the timber, and being unsuspicious venture into towns, where they may not unfrequently be seen searching for insects upon the roofs of houses, church-spires and such-like.

COLAPTES AURATUS (Linn.) *Yellow-shafted Flicker.*—An abundant winter visitor, arriving in considerable flocks about the last week of September; these flocks soon break up into pairs or small parties which remain associated during their stay, but before their departure in March they again collect together into large bands for the purpose of migrating. They are entirely frequenters of the more open lands, preferring the thinly-wooded districts on the outskirts of the river bottom and prairie creeks bordered by mesquite flats, to the dense timber, in which they are rarely seen, and only where old clearings occur. They are very shy and difficult

to approach. Their food consists of seeds and insects ; ants which they obtain as they pass in and out of their hills, being very commonly present. In many of their habits they differ from all our other woodpeckers, such as perching in the ordinary manner across the branch of a tree, and seeking their food upon the ground; the latter habit occasionally brings them into curious companionship, as for instance I have seen them feeding on a marshy meadow along with plover and curlews, several hundred yards distant from the nearest trees, and seemingly quite at home. The Red-shafted Flicker, VAR. MEXICANUS (Swains.) is rare here ; I obtained one specimen, an adult female, in an isolated clump of trees upon the prairie, on the 22nd December, 1879; it was very wild, and it was not for several days that I was able to get a shot at it. During the following month I saw a second example near the same place.

CERYLE ALCYON (Linn.) *Belted Kingfisher.*—This species is only a migrant with us, more commonly seen during September and October than at other times; this is probably due to the muddy colour of the water in the rivers and creeks which makes the capture of fish difficult if not impossible. I found them generally by clear pools of rain water along the borders of the timber, where they were feeding on crayfish.

GEOCOCCYX CALIFORNIANUS (Less.) *Chaparral Cock.*—I never had the good fortune to fall in with a specimen of this bird, though it is said to be found in the wooded districts, and has been accurately described to me many times. In Dallas county, forty miles further north, it is also not unfrequent, and I have seen a fine example from that locality, which is preserved in the collection of Dr. Thomas of Dallas.

COCCYZUS AMERICANUS (Linn.) *Yellow-billed Cuckoo.*—The rain-crow, as this bird is called here, from an erroneous idea that its cry is only heard before rainy weather, is an abundant summer visitor to this section, arriving about the second week in May and frequenting both the dense recesses of the timber, and also the thinly-wooded localities and clearings in the vicinity of towns and farm-steads. The only nest which I found was placed in the middle of a thick bush overgrown with vines; it contained five well-grown young in the beginning of July ; they bring out but one brood in a season. Occasionally these birds tap upon a tree in the same way as a woodpecker ; and I have frequently found

their stomachs crammed with the same kind of white grubs as those birds obtain. The noise made by them is quite as loud as that made by a sapsucker, but the bird sits in the usual way upon a branch, and strikes straight down. I have also found grasshoppers, beetles, wasps and bees among their food. Their migrations are performed in pairs, and I think generally with the wind.

ALUCO FLAMMEUS, AMERICANUS (Aud.) *American Barn-Owl.*—Though I have been told of the occurrence of this owl here, I never met with it, and it must be rare; I only allow it a place in the catalogue from the presence of a specimen in the collection of Dr. Thomas, obtained by himself in Dallas county.

ASIO ACCIPITRINUS (Pall.) *Shorteared Owl.*—A winter visitor in considerable numbers, frequenting old hayfields and patches of low weeds on the prairie, among which they lie during the day, though they appear to suffer no inconvenience from the brightest sun, and even at mid-day are wild and difficult to obtain, rarely allowing of an approach within gunshot. They arrive about the end of October, and do not remain long after the end of March. Occasionally they pass the day among the branches of a tree, those which are densely foliaged and stunted in growth being chosen. I have found mice, meadow-larks, Savannah sparrows, a small woodpecker, and remains of beetles in the stomachs of those which I examined.

STRIX NEBULOSA, Forst. *Barred Owl.*—The most abundant species of owl, and resident, frequenting the bottom lands and creeks. During the day they roost among the middle branches of thick trees, whence, if disturbed, they dart down to within a few feet of the ground, and make off with a rapid, noiseless flight, and generally alight very soon. They are exceedingly vigilant, and are not at all incommoded by the brightness of the sun, being able at any time to thread their way with ease between the stems and branches of the trees; and I have even shot one from off the body of a cotton-tail rabbit, which it was eating, during the afternoon. They breed both in the dense timber and in the creeks, and the young are well able to fly by the beginning of June. During the fall and winter they are common along the edges of the prairie, upon which they come out nightly, visiting the farms in search of rats and mice, and are accused of carrying off poultry

also. Their hooting is heard occasionally in the daytime and continually at night during the whole year.

SCOPS TRICHOPSIS, Wagl. *Mexican Screech-Owl.*—Since leaving Texas I have received, through the kindness of my friend, Mr. J. D. Tracy, a specimen of this owl. Being unable to decide satisfactorily to which form it belonged, I sent the example to Mr. Robert Ridgway, who considers that it approches most nearly to the above species or race. On several occasions I saw small owls flitting about in the gloaming, generally about open glades in the timber.

BUBO VIRGINIANUS (Gmel.) *Great Horned Owl.*—This fine species is not uncommon, but from its dislike to light, causing it to haunt the most impenetrable thickets of the river bottom, it is far more often heard than seen, so that I shot but one example, and saw very few others. They are accused of being very destructive to poultry on timber farms, their large size and strength enabling them to carry away an ordinary-sized hen with ease. They return night after night to the same roost for this purpose.

SPEOTYTO CUNICULARIA HYPOGÆA (Bonap.) *Burrowing Owl.*—Occurs not uncommonly during the winter months, lying concealed during the daytime among weeds in dry upland watercourses upon the prairie, and so closely that one almost treads upon them before they will take wing; nevertheless, they seem to suffer no inconvenience from even the strongest light Their food consists entirely of large insects, such as beetles and grasshoppers. The tarsi of those which I obtained were fully feathered to the toes anteriorly, though sometimes bare posteriorly. I have been told of their breeding in the district, but never came across them in summer.

HIEROFALCO MEXICANUS POLYAGRUS (Cass.) *Prairie Falcon.*—This fine species is not uncommon from the middle of October to the end of February, frequenting open districts dotted over with a few scattered trees or old stumps, upon the summit of which they take their stand for the purpose of surveying the surrounding country. When by chance they dispossess a kestrel of its regular seat, a most amusing encounter takes place between the birds, the latter, assisted by any others of its species within hearing distance, swooping down with angry cries towards the

falcon, which contents itself at first with ducking its head to avoid the blow, but at last is always compelled to vacate its perch. It is only during a contest of this kind that there is any possibility of approaching these birds, which at all other times are very wild. They fly with great swiftness, generally close to the ground, and feed upon prairie grouse, plover, curlews, &c.

FALCO PEREGRINUS NŒVIUS (Gmel.) *Duck Hawk.*—A scarce winter visitor, arriving with the migratory flocks of water fowl about October, and leaving with them in spring. While lying in wait for ducks at a prairie tank, I had an opportunity of witnessing an exciting chase of a shoveller by one of these falcons. When first observed, the duck was flying towards the tank in a hurried manner, and not more than twenty feet from the ground, and a moment afterwards I saw the falcon descend like a flash. On this occasion he missed his swoop, and the poor duck, actually screaming with affright, redoubled its efforts to reach the safety of the water, but, before this could be accomplished, its pursuer had risen again, and with a second and more successful swoop struck the duck into the water within a few feet of where I was standing. This example proved to be an immature male. Once I saw a chase somewhat reversed, when having wounded a peregrine, an adult male harrier which was passing at the time followed and struck it down in my sight.

ÆSALON COLUMBARIUS (Linn.) *Pigeon Hawk.*—I met with this little falcon only as a winter visitor, occurring between the months of October and March inclusive, and never in any quantity. They frequent the wooded banks of prairie creeks, and the borders of the dense timber, but I never found them in the river bottom lands. Their food consists almost entirely of small birds, such as sparrows, cowbirds, &c., but, when hungry, they do not hesitate to attack much larger species. On my way home, when passing through the Indian territory, a hawk agreeing in size with this species, but almost black in colour, flew past the train so close that I had a good view of it.

TINNUNCULUS SPARVERIUS (Linn.) *Sparrow Hawk.*—A winter visitor in very large numbers, arriving about the last week of August, and leaving before the end of April, and frequenting the open prairie and large clearings in the timbered districts in preference to the more thickly wooded lands. They are sedentary

in their habits, each bird choosing some old stump or dead bough as a stand from which to overlook the surrounding ground, and whence, on catching sight of a prey, they fly down, capture it, and carry it back to their seat, there to consume it at their leisure. Their food consists almost entirely of grasshoppers, but worms and small birds are occasionally taken, and I once saw a male bird chase a loggerhead, which, however, escaped by taking refuge among thick weeds.

POLYBORUS CHERIWAY (Jacq.) *Caracara Eagle.*—This species is not unfrequent upon the prairie, generally in pairs, but sometimes singly, at all seasons of the year. They may often be seen feeding upon the dead bodies of cattle, in company with vultures, but, as soon as putrefaction begins, the caracaras cease to feed on it, while the vultures seem to relish it the more. They feed also upon cotton-tail rabbits, lizards, grasshoppers, and beetles. They are shy birds, rarely, even when feeding, allowing of an approach within gunshot, and then only by a person riding. Their flight, though strong, is heavy, and before rising they have to run a few yards to gain sufficient impetus. The nest is placed high up on a tree, and is formed of sticks and twigs, lined with weeds, and the eggs are laid during March, the male assisting in their incubation.

ELANOIDES FORFICATUS (Linn.) *Swallow-tailed Kite.*—This beautiful bird arrives in our district about the beginning of April, and during that month examples may be seen almost every day, but generally at a great height. These probably pass on further north, as it was not until the middle of May that I remarked them to be plentiful in the timber along the river banks. During the last week in June I found them breeding gregariously in Richland Creek, the nests being placed on the upper branches of tall cotton woods bordering the creek, mostly away from the main trunk, and quite inaccessible. They did not appear to stir about much during the heat of the day, but appeared in large numbers about two hours before sunset, gliding immediately above the tops of the trees. About the middle of July they begin to visit the prairie in flocks consisting both of old and young birds, and numbering sometimes as many as two hundred individuals. These flocks gradually dwindle away during August, until by the end of that month all have gone south. At

this time they feed entirely upon grasshoppers, beetles, and locusts; their utility is therefore unquestionable. They do not hunt together in a close body, but scatter far and wide over the prairie, all, however, having a general direction the same way. I have thus had many opportunities of admiring the grace and buoyancy of their flight, but was never so much struck by it as once when resting among some mesquites on the prairie, when a kite was feeding upon the singing locusts, which are always to be found on those trees. It would sail slowly over the top of a tree, striking the upper branches with its long wings as it passed, and as soon as the locust darted out, it would throw itself forward by a sudden flap of the wings, and at the same moment thrust forward its foot so far that it seemed almost to turn over on its back in the air, seize the insect in its claws, and stripping off the hard parts by a sideways action of the bill, transfer the remainder to its mouth; and this, which takes so long to describe, was done almost instantaneously, nor did I once see it fail to capture the insect. When first I arrived, but one bird was thus engaged, but others, soaring so high that the eye could barely detect them against the sky, soon observed its actions, and, closing their wings, dropped swifter than sight could follow, and, when nearing the tree-tops, checked their speed by a sudden expansion of their wings, just as they appeared about to be dashed upon the ground, then, with a few graceful beats of their long pinions, they commenced operations for themselves. I can compare the noise made in their downward plunge to nothing but that produced by the rising of a rocket into the air. I never saw these hawks alight upon the prairie, nor indeed anywhere except on the upper branches of tall trees.

Ictinia subcærulea (Bartr.) *Mississippi Kite.*—A common summer visitor to the thick timber along the river banks, being, like the last species, more or less gregarious at all times, but especially so in the autumn. They leave this district about the beginning of September. They may generally be seen circling above their breeding haunts at a considerable height, and their power of wing is very great; when seated they choose the loftiest branches of dead trees. Their food appears to be formed entirely of insects. I never observed one of these kites upon the prairie.

Circus hudsonius (Linn.) *Marsh Hawk.*—This is by far the

most abundant of the large hawks upon the prairie, to which it is a winter visitor, arriving about the middle of September and leaving during April. The females and young precede the adult males by fully a month in the fall migration, but I never remarked any separation of the sexes prior to their departure in spring. Although generally roosting upon the ground among long grass, they not unfrequently choose a fence, or even one of the lower branches of a tree, for this purpose. When searching for food, they generally follow the same beat day after day, examining every foot of the ground with the utmost minuteness, and upon observing a prey close their wings, and seem to fall on the top of it. They never or very rarely pursue a bird on the wing, and so well is this understood that, on their approach, all the small birds in the neighbourhood rise into the air. Cottontail rabbits and meadow larks seem to be their ordinary food, but nothing edible comes amiss to them. In one very large female the breast, abdomen, crissum, and lower tail coverts were immaculate, but in all others broadly striped. A careful measurement of the tarsi of a number of specimens gave—males, 2·80–2·90; females 3·30–3·40.

ACCIPITER COOPERI, Bonap. *Cooper's Hawk.*—So far as my observations go this species is only a winter visitor, and much more abundant in the fall than at any other season. They may then be found in all the open districts, seated on low trees and fences, or skimming quickly by, a few feet from the ground, but in winter those which remain haunt the edges of the timber in the neighbourhood of farm buildings, feeding chiefly on doves, larks, and such poultry as they can carry off, the swiftness and noiselessness of their flight allowing them to perform their robberies with a minimum of danger to themselves.

ACCIPITER FUSCUS (Gmel.) *Sharp-shinned Hawk.*—A winter visitor in small numbers to the more open districts. They prefer isolated clumps and narrow belts of trees on the prairie, to which they resort nightly to roost, but during the day are found about farms and open lands, where they feed on small birds, which they procure by gliding swiftly and stealthily from behind the cover of an out-house, fence, and such like, and so silently that the victim is seized and carried off before its comrades have time to realize what has happened.

Buteo borealis (Gmel). *Red-tailed Hawk.*—This form is common and resident, frequenting during the breeding season the dense timber as a rule, though sometimes forming its nest in the prairie creeks; in winter they are much more frequently found upon the prairie, where they may be seen daily perched among the branches of isolated trees or upon the worm fences. Their principal food at all seasons consists of grasshoppers, which they seek on foot, running after them in the same manner as poultry do; meadow larks and cottontails are also a favourite prey, and they are strong enough to bear off one of the latter, even when full grown, with ease. I kept a young bird, which I had winged, for some time; after a while it got comparatively tame, but always was jealous of observation while eating, drawing its wings forward in front of its head, so as completely to conceal its actions; it swallowed the bones, fur, or feathers, along with the flesh, but subsequently disgorged them in the form of pellets. It drank very little and seldom. During November, 1880, I shot a hawk, which corresponded in markings with the variety separated as B. krideri. The *Western Redtail*, B. calurus (Cass.), is a common winter visitor, arriving about the middle of October and leaving during March. This bird differs in some of its habits from its eastern representative. They return year after year to the same locality, each one making choice of some prominent, generally dead, tree, whence it may obtain an extended view; and, except when engaged in hunting, they may be seen at all hours of the day on the favoured perch. They do not, however, roost there. This form frequently hovers with gently moving wings like a kestrel, which the other never does. They are much more wary and are more carnivorous in their propensities, never, I think, feeding on grasshoppers.

Buteo lineatus (Gmel.) *Red-shouldered Hawk.*—Common and resident, frequenting for the most part the thickly-timbered districts, though young birds are occasionally killed upon the prairie during the fall. With the exception of one example, which had eaten a lizard, the stomachs of all those which I shot contained insects only. They are not at all shy, and their presence may always be detected by a querulous, mewing sort of cry which they continually utter both when perched and on the wing.

Buteo swainsoni, Bonap. *Swainson's Hawk.*—This species, which is quite as unsuspicious as the preceding, is common on the prairie during the fall. They feed upon grasshoppers, and though often soaring in wide gyrations at a great height, may generally be seen perched on a low tree, a stump, or even the ground.

Buteo pennsylvanicus (Wils.) *Broad-winged Hawk.*—A winter visitor to the open districts in small numbers. It is excessively watchful and suspicious, so much so that it was only on one occasion that I managed to get within range of a specimen.

Cathartes aura (Linn.) *Turkey Buzzard.*—Resident and numerous in our district, but more abundant upon the prairie than in the wooded districts, where its place is in great part taken by *C. atrata.* At all hours of the day they may be seen soaring, often at such enormous heights as to appear but a speck in the sky, yet from this elevation its extraordinary range of vision enables it to distinguish any dead or dying animal upon which it immediately descends in wide gyrations. When ascending also it rises to the required height in ever increasing spirals, after which it soars in huge circles with motionless wings The indigestible portions of their food, such as hair and fur, are rejected in round pellets. Common as they are, I was unable to find a nest of these vultures, but several informants have told me that they lay their eggs upon the ground beside a fallen tree, or upon ledges of the steep banks of creeks.

Catharista atrata (Wils.) *Black Vulture.*—Abundant in all the wooded districts, and especially frequenting the neighbourhood of towns and villages, near which it may be seen at all times seated on the trees and fences, and where its utility in clearing off all dead animal matter, which by its rapid decomposition might otherwise engender sickness, is recognised by its immunity from harm.

Zenaidura carolinensis (Linn.) *Mourning Dove.*—Though individually migratory, these beautiful doves are exceedingly numerous at all seasons, and in all localities, the open prairie and the dense timber being haunted alike. They are useful in the neighbourhood of farms from the enormous amount of seeds of the sunflower, knot-grass and other weeds which they consume. Their nest, a very simple affair formed of a few crossed twigs, is placed in various

localities, either on the ground, a branch of a tree, or even a corn stalk, and several broods are produced during the season, fresh eggs being found at any time between March and September.

MELEAGRIS GALLOPAVO AMERICANA (Bartv.) *Wild Turkey.* —The wild turkey is still a common resident in the county, frequenting the wooded districts, but owing to its naturally shy disposition, and the incessant persecution to which it is subjected, it is very difficult to get a sight of the birds, even where they are numerous. The reprehensible practice of calling up the gobblers, and shooting them, which can only be done during the spring of the year when they are breeding, makes them, by killing off all the male birds, much scarcer than they would otherwise be, and must, if persisted in, ultimately cause the disappearance of this noble species from the district.

CUPIDONIA CUPIDO PALLIDICINCTA, Ridgw. *Lesser Prairie Hen.*—Very common and resident. During the autumn, winter, and spring months, they assemble in flocks, numbering sometimes as many as two hundred, and are then very wild and exceedingly difficult to obtain. During the month of November the greater number leave the prairies and fields and go down into the wooded districts to feed upon the fallen acorns. They pass the heat of the day in thick covert, either long grass or the shady margins of creeks, coming into the cultivated lands to feed in the morning and evening. They frequently fly up into trees when disturbed, and it is then useless to attempt to approach them; sometimes, indeed, specially during cold weather and snow, they spend whole days among the branches of trees. During March they begin to drum, and may be heard so engaged about sunrise every morning; during the next three months they are seldom seen, being busied with the duties of incubation in the most secluded retreats. About the middle of July the packs begin to appear on the prairie, led by the old hen, but never accompanied by the male; the young are then strong on the wing and fat; when disturbed they fly to the nearest covert whether of dense weeds or shrubbery, from whence it is next to impossible to dislodge them. Their food consists of maize, the seeds of the sunflower and other weeds, the leaves of the cotton, various flowers, and where obtainable they are very partial to melons. The old males grow to a large size occasionally attaining

a weight of 38 oz.; the average weight of fifty birds shot during November and December was about 30 oz.

ORTYX VIRGINIANA TEXANA (Lawr.) *Texan Quail.*—These beautiful little birds are very common with us, frequenting the cornfields and edges of the wooded creeks which intersect the prairie. In winter they show the greatest preference for wooded localities going in coveys of from ten to thirty individuals, and lying so close as to be almost unobtainable without a good dog. They frequently perch upon trees. During the spring they come in pairs into the fields or up the dry watercourses upon the prairie, where morning and evening their monotonous but not unmusical callnote may be heard on every side; the earliest date on which I heard them call in 1880 was May 7. They form their nests among long grass in low-lying localities, but numbers of eggs are lost by being laid promiscuously, chiefly about the edges of prairie paths. Occasionally a wounded bird will tower as does a grouse. Their average weight is about $6\frac{1}{4}$ oz. but now and then a patriarchal specimen attains to $7\frac{1}{2}$ oz.

ARDEA HERODIAS, Linn. *Great Blue Heron.*—This species seems to be very rare here, since I observed but three examples, one of which was obtained.

HERODIAS ALBA EGRETTA (Gmel). *American Egret.*—A summer visitor in considerable numbers, frequenting the borders of rivers and ponds in the thick timber. During the autumn, single birds may frequently be found about the margins of prairie tanks, about which they sometimes remain for several weeks; I never observed one later than the middle of September. Their food then consists chiefly of crayfish and grasshoppers with an occasional lizard.

GARZETTA CANDIDISSIMA (Gmel).—*Snowy Heron.*—These beautiful little herons are not uncommon in the low-lying wooded districts during the summer, and are then so unsuspicious that I knocked down my first specimen with a stick, after watching it for several minutes searching for crayfish in the shallow water of a puddle within a few feet of where I was standing. Arriving about the beginning of May, they immediately retire to the dampest and most impenetrable parts of the river bottom, where they remain unmolested until the young are sufficiently strong

to undertake more protracted flights. About the middle of July small flocks begin to appear upon the prairie, feeding during the day time upon the low-lying parts and continuing their journey by easy stages during the night: by the end of September, even the last stragglers have passed south. Two or three small blue herons, probably belonging to the next species, are generally found associated with the migratory flocks, and, on one occasion, I saw what appeared to be a perfectly black example.

FLORIDA CÆRULEA (Linn). *Little Blue Heron.*—Arrives in numbers during April, frequenting the prairie creeks, so long as water remains therein; but where these have dried up, retiring to the margins of the river and woodland ponds, where they rear their brood; and these may occasionally be seen in their white plumage about the tanks, on the prairie, from the middle of July until the third week of August, by which date both old and young have disappeared. Their food consists of small fishes, grasshoppers, beetles and the inevitable crayfish.

NYCTIARDEA GRISEA NÆVIA (Bodd). *Black Crowned Night Heron.*—Though on two occasions I saw what I believed to be this bird, I can only allow it a place here from having examined a beautiful specimen in the collection of Dr. Thomas, of Dallas, shot by himself in that locality.

NYCTHERODIUS VIOLACEUS (Linn.) *White Crowned Night Heron.*—Appears to be a scarce summer visitor to the damp and unfrequented parts of the timber where they breed, leaving for their winter quarters during August. Like most other herons, the young birds may often be seen on the prairie during that and the preceding month, where they easily gain their subsistence on grasshoppers and crayfish.

BOTAURUS LENTIGINOSUS (Montag.) *American Bittern.*—A rare migrant in our district, passing quickly through during March and October; they perform their migrations entirely by night, remaining concealed for the most part during the day time among long grass and weeds, where they lie so close that it is exceedingly difficult to rouse them; they fight with great courage and determination when only wounded. They feed upon the usual crayfish and insects.

CHARADRIUS DOMINICUS, Müll. *American Golden Plover.*—During the first week in March enormous flocks of these plover

appear upon the prairie resorting to the low-lying flats along the edges of the creeks, especially where these have been lately overflowed. They are at first by no means wild, often allowing the sportsman to walk within easy range, and when one of a flock is killed, frequently sweeping round over the body of the victim, and thus affording an easy shot to the second barrel. A very few days however teach them caution, and they then become exceptionally wild. Their numbers are so great that I have often received my first notice of the approach of a flock through the noise made by their wings, which may be heard at a great distance, and long before the flock itself becomes visible, sounding as if a strong breeze were approaching. By the middle of April the spring migration has ceased. They are very scarce during the fall, passing in small parties in August and September, and according to my experience, never alighting.

Oxyechus vociferus (Linn). *Kildeer*—This pretty species is resident in our county, and is usually found in summer upon bare sandy places, about which a few mesquites are scattered, beneath the shade of which they pass the heat of the day. In such places they probably form their nests, which, however, I never succeeded in finding; the cause of my failure in this may possibly have been that I commenced my search too late, since, I found young birds which must have been some days out of the shell during the last week of April. During the autumn and winter they may invariably be met with upon fallow lands, and places where the prairie has been turned up for the first time preparatory to cropping. They are very confiding, rarely flying far even when fired at, and, at all times, allowing a near approach. During March, large flocks pass northward in company with curlews and golden plover; but, on the return migration, which occurs in October and November, they are unaccompanied. Their food consists of insects of all kinds and in all stages, and is always plentifully mixed with fine gravel.

Gallinago media wilsoni (Temm.) *Wilson's Snipe.*—Very scarce in this district, owing to the absence of marshy land, so that they are only found during the seasons of migration and during winter in isolated spots which heavy rains have flooded. They are very tame, never flying more than fifty yards, even when fired at, and lying until they are almost trodden on. Their

cry is exactly similar to that of our form. The stomachs of the two which I examined were filled with small beetles, most of them perfectly whole.

Macrorhamphus griseus (Gmel.) *Grey Snipe.*—I obtained my only example of this handsome wader on the last day of August, 1880, while feeding, in company with *Actodromas maculata.*

Micropalama himantopus (Bonap.) *Stilt Sandpiper.*—Occurs not unfrequently along the edges of prairie tanks during August and September; but, unlike other allied species they are usually found singly, and are therefore more than ordinarily tame and unsuspicious. This is one of the only species of sandpipers in whose stomach I have found remains of vegetables, such as seeds, blades of grass, &c., in addition to worms and small aquatic insects.

Actodromas maculata (Vieill.) *Pectoral Sandpiper.*—A very scarce migrant in our district, though appearing at both seasons, especially during May and the latter half of August. They are not confined to the neighbourhood of water, but are not uncommonly found, especially during the spring, consorting with allied species on the sandy uplands, where they feed on small grasshoppers and beetles.

Actodromas minutilla (Vieill.) *Least Sandpiper.*—Occurs rarely during the northward migration in April, but on their return in August and the first half of September, they are the most abundant of the smaller waders, frequenting the muddy margins of prairie tanks, though occasionally found associating with *Tryngites rufescens,* on sandy patches remote from water. They are generally found in family parties of five or six, but sometimes, and especially towards the close of the migration, flocks of two or three dozens may be seen. They are at all times unsuspicious, carrying on their ordinary avocations within a few feet of the observer, of whom they evince no fear. They feed upon minute insects, and though a few seeds may now and then be detected, their presence is perhaps due to accident.

Pelidna alpina americana, Cass. *Red-backed Sandpiper.*—I obtained a fine adult male in full summer plumage upon the 29th April, 1880. It was accompanied by a mate, and both were feeding on a bare patch of sandy ground along with a flock of buff-breasted sandpipers, with whom, however, they did not

intimately associate, either while feeding or in flight. The stomach was crammed with small beetles and gravel. I observed another example on the 29th August by a tank, thus proving that the species is a rare visitor to the district at both seasons of migration.

EREUNETES PUSILLUS (Linn.) *Semipalmated Sandpiper.*—An autumn migrant in considerable numbers, frequenting the margins of prairie tanks during August and the early part of the succeeding month in company with *Actodromas minutilla* and *Totanus flavipes*, from the former of which, however, it is easily distinguishable, even in flight, looking both larger and lighter-coloured than that species. Their food consists of small insects, in search of which they wade out far into the water, frequently out of their depth, in which case they swim well and strongly. The great diversity in the length of the bill, which ranges between 0·68 and 0·92, struck me as remarkable in this species, even among waders.

TOTANUS MELANOLEUCUS (Gmel.) *Tell-tale.*—A common migrant in our section, passing northward during the latter half of March and early part of April, when they are met with singly about the edges of prairie pools and creeks, but during the last week of September and October large flocks appear in suitable places, where, however, they only remain one day, even when unmolested, passing on during the following night, this migration being performed much more rapidly and regularly than the spring passage. They are most expressively called "Tilt-up" here, from their habit of rocking the body forwards when seated.

TOTANUS FLAVIPES (Gmel.) *Yellow-legs.*—During August and September these birds pass in large numbers, but, unlike their larger congener, they appear to be in no way hurried at this season, frequently remaining about a suitable tank or pool for several days, besides which they are almost invariably found singly or in pairs, though usually consorting with other species; indeed I only saw more than two in company on one occasion, when a flock of about fifty rested for a day by our tank. They are the most utterly unsuspicious birds I ever met with—so much so that I have often shot one of a pair, and its companion has continued to feed beside it, perfectly unconcerned at the noise of the report or the death of its mate. Their food chiefly consists of water beetles and their larvæ.

Rhyacophilus solitarius (Wils). *Solitary Sandpiper.*—A scarce migrant through our district, occurring singly during April by prairie pools and tanks, and again returning during August and September, frequenting similar localities and feeding on small crayfish, shells, and insects. They show the greatest aversion to the presence of any individual, whether of their own or an allied species. They have the same habit of tilting the body observable in the two preceding species. Though carefully sought for by woodland ponds and streams, I never met with this species except upon the open prairie.

Symphemia semipalmata (Gmel.) *Willet.*—A very scarce visitor at both migrations, passing northward during March, when I saw two specimens at different times in company with flocks of *Numenius borealis*, while but one came under my notice during the following October, when I shot it from a pool of rain water in a prairie creek.

Bartramia longicauda (Bechst.) *Field Plover.*—An abundant summer visitor, arriving during the last week in March, and remaining with us until the middle of September. An occasional straggler may, however, be found, even as late as the third week of October. For about a month after their arrival, they frequent the higher parts of the prairie, but towards the end of April those that remain with us, having paired, retire to the shelter of hay and corn fields, where they may with the greater security bring out their brood. About the beginning of July, the family parties, consisting of two old and four young birds, begin to appear upon the prairie, frequenting, during the heat of the day, the edges of dry watercourses and disused roads, along which the growth of tall weeds shelters them from the sun; thence, towards evening, they spread themselves over the adjoining prairie, more often by running than flying. In August small migratory flocks begin to appear, and as the season advances these increase in numbers, so that during the first week in September they sometimes number thousands. They are partial to those parts of the prairie which have been freshly burned, and resort thither in large numbers, not, however, feeding together, but each one according to its individual fancy; nor do they associate, either on the ground or in flight, with other species. At this season they give excellent sport, rising at a distance of from ten to twenty-five yards, and

going straight away, and as they are excellent eating and very plump, they are well worth shooting. They alight frequently upon wooden fences, but I never saw one perch on a tree. Like the golden plover, they expand the wings and raise them vertically above the body upon first settling and when about to take flight. Their food consists altogether of insects, more especially grasshoppers.

TRYNGITES RUFESCENS (Vieill.) *Buff-breasted Sandpiper.*—Though occurring at both seasons of migration, this handsome sandpiper must be considered rare in our district. During the two last days of April, 1880, I saw several small flocks, but lost sight of them altogether from that time until September 21st, when I again observed a party. They invariably resort to dry sandy tracts of upland prairie, where they find an abundance of coleopterous insects on which to feed.

TRINGOIDES MACULARIUS (Linn.) *Spotted Sandpiper.* — A summer visitor in small numbers, arriving towards the end of April and remaining until the middle of September. During the daytime they retire into the recesses of the forest, from whence they issue shortly before sundown, and seek the banks of the river and the ponds in the timber districts, where they feed upon water insects, and are frequently found consorting with *Siurus* in such localities. It is only during the seasons of migration that these birds are ever observed on the prairie, and even then very rarely, and always in immature plumage.

NUMENIUS LONGIROSTRIS, Wils. *Long-billed Curlew.*—These curlews appear at intervals between the first week of August and Christmas, generally in flocks but sometimes singly, frequenting dry upland stretches of prairie, and feeding upon grasshoppers and other insects.

NUMENIUS BOREALIS (Forst.) *Eskimo Curlew.*—Like many other species, this handsome little curlew is found plentifully in our district during the spring migration, but takes some other route on its southward journey in the fall, when it never appears with us. Arriving about the middle of March, they spread themselves over all the low-lying swampy parts of the prairie in company with *Charadrius dominicus.* They are generally found in considerable flocks and are then invariably difficult of approach, but when feeding singly they rather prefer to conceal themselves by

lying flat along the ground with the head and neck stretched out in front, than to escape by flying.

STEGANOPUS WILSONI (Sab.) *Wilson's Phalarope.*—This species is probably a regular, though scarce, migrant during the fall, as I met with it on three occasions at least, between the 3rd and 12th September, 1880. I never saw more than two together, and always accompanying flocks of waders; nor did I once observe them floating on the water, but invariably seated on the ground beside a tank.

RECURVIROSTRA AMERICANA, Gmel. *American Avocet.*—The only example of this graceful wader which I obtained was shot beside a prairie creek on the 22nd October, 1880. When fired at and winged it swam across the pool, a distance of about twenty feet, and regardless of its own wound and my presence, began with consummate nonchalance to seek for food upon the other side. Its stomach contained shells, a few small insects, one cray-fish, and a large quantity of gravel.

PORZANA CAROLINA (Linn). *Sora Rail.*—During the month of September these pretty little rails are not uncommon in the cultivated fields, which they seem to frequent in preference to the damper parts of the prairie. They are semi-crepuscular in their habits, and are therefore much easier found and raised about sundown than during the day time. They often settle upon a rail in a fence, if one be near when they are disturbed. The food consists of various seeds intermixed always with gravel.

FULICA AMERICANA, Gmel. *American Coot.*—Occurs sparingly along the banks of the Trinity during April; and in much greater numbers during October, when they are more usually found in small ponds of rain-water along the borders of the woodlands, usually in company with teal, but unlike them they are very tame, scarcely troubling themselves to swim out of the way. They feed on worms, shells, water-insects and grass.

GRUS AMERICANA (Linn.) *Whooping Crane.*—This species passes in considerable numbers both at the spring and fall migrations, and is easily distinguishable from its more abundant congener both by colour and size. They begin to pass northward about the last week of March, and the migration continues about three weeks: they also differ from the succeeding species in performing their journey in much smaller numbers, so that twenty

is the most I have seen in a flock. October is the season of the return migration. These birds frequently alight upon the prairie and even in the cultivated fields, but they are so shy that it is impossible to get within range even for buckshot.

Grus canadensis (Linn.) *Sandhill Crane.*—Like its congener this species is merely transient with us, passing north in enormous flocks during the last week of March and April, and frequently accompanied by numbers of geese. The return migration is much more protracted, few days passing between the middle of September and the beginning of December on which flocks may not be seen. They feed and rest upon the prairie at night, rising at dawn, and ascending in huge spirals to a very great height, when with one accord the whole band starts off on its journey. A curious fact is that when passing north the route taken has a general tendency to the N.E., while the southern migration tends to the S.E., or across the line of the northern passage. The same remark applies to the migration of the snow geese.

Olor (sp.) ?— On two occasions I observed swans during the month of November, but both times passing at a considerable distance. I was however informed by a friend of a specimen which was shot near Corsicana during the winter of 1879–80, but was unfortunately unable to obtain a sight of the example so as to determine the species. From the description I believe it to have been *O. buccinator.*

Chen hyperboreus (Pall.) *Snow Goose.*—The chief migration of these geese occurs during October, but much depends on the state of the weather further north, which either retards or hurries their passage according to its clemency or severity; and indeed all through the winter flocks may be seen at intervals, a sure sign of a coming increase of cold.

Bernicla canadensis var. hutchinsi (Sw. and Rich.) *Hutchins's Goose.*—The same remarks apply to the migration of this species as to the preceding, but these birds are far more plentiful than their more beautiful relatives, and on account of their lighting in large numbers on the prairie to feed and bathe, are much more easily obtained. I never saw geese of any sort during the spring migration.

Anas boscas, Linn. *Mallard.*—An abundant winter visitor, arriving about the middle of September, and frequenting the ponds

in and about the margins of the wooded districts in preference to the tanks on the open prairie, upon which indeed I but rarely found them. Though passing in large flocks during the fall it is strange that, as with many other species, the return journey of the main body seems to lie along a different route, or at least passed quite unnoticed though carefully looked for.

ANAS OBSCURA, Gmel. *Black Mallard.*—Occasionally found in winter, accompanying flocks of the preceding species, and frequenting similar localities.

CHAULELASMUS STREPERUS (Linn.) *Gadwall.*—During the month of October these ducks pass in myriads, spending the day on the prairie tanks, and continuing their journey by night. At this time they are excellent eating and very fat, and are shot in large numbers, meeting with a ready sale at ten cents apiece in the neighbouring towns. These birds are almost always found associated with the next species, and with them form the great majority of ducks on the prairie.

MARECA AMERICANA, (Gmel.) *Baldpate.*—From the middle of October to that of November this was the most abundant species of duck, frequenting indiscriminately the tanks on the prairie, and those along the border of the woodlands, but never found on the river or overflow ponds in the densely timbered districts. They go in large flocks and are easily approached even on open tanks by leading a horse in such a way as to screen the sportsman from view.

SPATULA CLYPEATA, (Linn.) *Shoveller.*—Occurs in both passages, but much more abundantly in the fall than in spring. In the latter I used occasionally to see single birds, always adult males, about prairie tanks and pools of rain-water, but they were never plentiful, whereas in the former they begin to appear in small flocks or perhaps family parties of from ten to fifteen individuals, about the last week of September and so continue passing slowly south until the end of the following month, after which they become much scarcer, and indeed, with the exception of single birds, always in wretched condition, do not occur at all. I shot at different times several of these stragglers, and invariably found them suffering from some internal disease which turned the intestines almost black, and since out of the number of ducks which I shot, I observed no other species to suffer from a similar complaint I do not think

this to be due solely to gun-shot wounds, as suggested by several friends, but rather to be a disease to which this species is peculiarly liable. Their mode of feeding is very interesting; stretching out the neck to its full length they swim slowly along, alternately sucking in the water at the surface, and ejecting it through the lateral lamellæ, which holds as in a net the small insects taken in with the water.

Querquedula discors (Linn.) *Blue-winged Teal.*—This fine teal is a winter visitor to our district, arriving about the middle of September and continuing to be very plentiful during the next six weeks, when they become much scarcer. They frequent the river banks, creeks and ponds in the timber, and seldom alight on any water unless in the immediate neighbourhood of trees. They are always found in considerable flocks and when approached crowd together as if for safety, a fatal mistake for them as it is not uncommon to obtain several, even as many as a dozen, at one discharge.

Nettion carolinensis (Gmel.) *Green-winged Teal.*—A regular winter visitor but in much smaller numbers than the preceding species, from which it materially differs in many habits; though frequently found in similar localities the green-wing is very fond of narrow muddy ditches and creeks, nor does it go in large flocks, but generally singly or in pairs, or in small companies of less than a dozen. They are also very wild, and even when approached do not crowd together, but rather both swim and fly wide apart I shot several during March while migrating and was surprised to find that all either obtained or seen then were adult males.

Aix sponsa (Linn.) *Wood Duck.*—A male and female of these beautiful birds seen on the 12th March, 1880, were the only examples which came under my notice during my stay in Texas.

Clangula albeola (Linn.) *Buffle-head.*—A winter visitor to the woodland ponds of our district, but very scarce and difficult to obtain, so much so that I obtained but one specimen though I saw several others between the months of December and March.

Erismatura rubida, (Wils.) *Ruddy Duck.*—A winter visitor in considerable numbers to the woodland ponds and tanks, arriving about the middle of October; they are always found in pairs, and each pond generally holds but one pair, though if these be shot another takes their place within a short time. They are adepts

at diving, by which alone they seek to escape danger, never attempting to fly, and they swim very low in the water, with the head stretched out in front close down to the surface, and sink when fired at with wonderful celerity.

MERGUS MERGANSER AMERICANUS, Cass. *American Sheldrake.*—I shot a fine specimen of this duck from a flock of twelve upon the 6th December, 1880, at a small pond in the woodlands. This was the only occasion on which I saw them.

LOPHODYTES CUCULLATUS (Linn.) *Hooded Sheldrake.*—This beautiful duck is a regular visitor to the woodland waters of our county, arriving about the middle of November and remaining until well on in March. They are shy birds, and very difficult to obtain, since even when approached within easy range they dive so quickly that it is a hard matter to hit them, and if untouched they rise out of range and immediately take wing.

PELECANUS ERYTHRORHYNCHUS, Gmel. *American White Pelican.*—During a heavy norther in October, 1880, a pair of these unmistakable birds passed over our house going in a south-easterly direction. These were the only living specimens which I observed, but there is a fine example from the neighbourhood of Dallas in the collection of Dr. Thomas of that city.

PLOTUS ANHINGA, Linn. *Snake-bird.*—An example of this curious bird was caught in a net in an overflow pond in the timber during August, 1879. Though in an advanced stage of decomposition when it came under my notice, it was of course easily recognizable. Its captors called it a water-turkey.

LARIDÆ (sp.)?—During October, 1880, a large straggling flock of gulls passed me on the prairie, but unfortunately out of range. They were of two species, the most numerous being about the size of and similarly coloured to the herring gull and may have been *L. smithsonianus*; the second was of the size of the black-headed gull and was probably *L. franklini.*

PODILYMBUS PODICEPS (Linn.) *Thick-billed Grebe.*—I shot the only specimen of this bird which I saw on the 20th October, 1880, at a tank on the open prairie; its stomach was crammed with grass among which were a few small beetles. During the fall I frequently saw a large brown grebe in the ponds of the timber districts but they were so wild, and dived so quickly when fired at that I never succeeded in obtaining a specimen for identification.

XXII.—NOTE ON MR. J. J. THOMSON'S INVESTIGATION OF THE ELECTRO-MAGNETIC ACTION OF A MOVING ELECTRIFIED SPHERE, BY GEORGE FRANCIS FITZGERALD, FELLOW OF TRINITY COLLEGE, DUBLIN, AND ERASMUS SMITH'S PROFESSOR OF NATURAL AND EXPERIMENTAL PHILOSOPHY IN THE UNIVERSITY OF DUBLIN.

[Read, November 21st, 1881.]

In the April number of the "Philosophical Magazine" for the present year Mr. J. J. Thomson has given an interesting investigation of the electro-magnetic action of a moving electrified sphere.

On the fourth page (*l.c.* p. 232) of this investigation, he makes an assumption which he does not justify in order to make the components of the vector potential of electro-magnetic induction satisfy the condition—

$$\frac{dF}{dx} + \frac{dG}{dy} + \frac{dH}{dz} = 0.$$

As it seemed very likely that they ought to satisfy this condition, I thought it worth while bringing before the Society a justification of his assumption which, however, leads to slightly different equations from his, though his final result is unaffected.

Mr. Thomson has not touched the question of the discontinuity at the surface of the sphere, nor what becomes of the displacement when the sphere passes over a point. We may assume that the point remains in its displaced position, and this is practically what Mr. Thomson assumes, but if we do the above condition is not fulfilled. We may assume that it returns to its original position, so that no permanent displacement takes place in the track of the sphere as would occur on Mr. Thomson's assumption. This, however, does not satisfy the condition either, and I have been led to assume that the particle does return to its original position, but that in some way or other the discontinuity at the surface acts as if a moving quantity of electricity acted like an

element of an electric current. This may seem like begging the question, but it is only doing explicitly what Mr. Thomson does implicitly. It is evidently impossible that the electro-magnetic action of moving electricity can be due entirely to the electro-magnetic action of the displacement currents in the dielectric, for in the case of a plane moving parallel to itself there are none of these displacement currents, and yet that is the only case that has been experimentally verified.

To show that my assumption leads to equations satisfying the condition, and leading to practically the same results as Mr. Thomson's, does not require much work.

Consider an elementary volume $dx\, ds. \cos\theta$, where ds is an element of the surface of the sphere, and θ the angle the radius makes with x. The displacement in this volume is $=\delta$ the superficial density while after the time dt it is zero on my assumption. Hence calling the displacement D, we have—

$$\frac{d\mathrm{D}}{dt}\,dt = -\,\delta\,.\,dx\,ds\,.\cos\theta.$$

Hence
$$\dot{\mathrm{D}} = -\,\delta\,.\,\frac{dx}{dt}\,.\,ds\,.\cos\theta.$$

Now $\dfrac{dx}{dt} = p$ the velocity of the sphere which is supposed to be moving along x. Hence the components of $\dot{\mathrm{D}}$ are $\dot{f}$, $\dot{g}$, $\dot{h}$, and observing that $ds = a^2 d\mu d\phi$ where $\cos\theta = \mu$ and a is the radius of the sphere, while $4\pi a^2\,.\,\delta = e$ the total quantity of electricity on the sphere.

$$\dot{f}\,dxdy\,dz = -\frac{ep}{4\pi}\,\mu^2 d\mu d\phi.$$

$$\dot{g}\,dxdy\,dz = -\frac{ep}{4\pi}\,\mu\cos\phi d\mu d\phi$$

$$\dot{h}\,dxdy\,dz = -\frac{ep}{4\pi}\,\mu\sin\phi d\mu d\phi.$$

Hence the components of the electro-magnetic potential are at a point at a distance—

$$\mathrm{F}_s = -\frac{ep}{4\pi}\iint\frac{\mu^2}{r}\,d\mu d\phi.$$

$$\mathrm{G}_s = -\frac{ep}{4\pi}\iint\frac{\mu\cos\phi}{r}\,d\mu d\phi.$$

$$\mathrm{H}_s = -\frac{ep}{4\pi}\iint\frac{\mu\sin\phi}{r}\,d\mu d\phi.$$

These are the components of the electro-magnetic potential due to this superficial change of displacement that I have assumed. When integrated over the surface of the sphere they give at a point distant R from its centre, and whose polar angles are a and ε

$$F_s = -\frac{ep}{3R} - \frac{epa^2}{5R^3}(\cos^2 a - \tfrac{1}{3}).$$

$$G_s = \quad -\frac{epa^2}{5R^3}\cos a \,.\, \sin a \,.\, \cos \varepsilon.$$

$$H_s = \quad -\frac{epa^2}{5R^3}\cos a \,.\, \sin a \,.\, \sin \varepsilon.$$

If we add to these the components calculated by Mr. Thomson, as due to the external displacement currents, and given by him (*l.c.* p. 233), namely—

$$F_e = \frac{ep}{10R^3}(5R^2 - 3a^2)(\cos^2 a - \tfrac{1}{3}).$$

$$G_e = \frac{ep}{10R^2}(5R^2 - 3a^2)\cos a \sin a \cos \varepsilon.$$

$$H_e = \frac{ep}{10R^2}(5R^2 - 3a^2)\cos a \sin a \cos \varepsilon.$$

we get as the resultant values of the components produced by the displacements assumed—

$$F_d = -\frac{ep}{3R} + \frac{ep}{2R^3}(R^2 - a^2)(\cos^2 a - \tfrac{1}{3}).$$

$$G_d = \quad \frac{ep}{2R^3}(R^2 - a^2)\cos a \sin a \cos \varepsilon.$$

$$H_d = \quad \frac{ep}{2R^3}(R^2 - a^2)\cos a \sin a \sin \varepsilon.$$

which however do not satisfy the condition—

$$\frac{dF_d}{dx} + \frac{dG_d}{dy} + \frac{dH_d}{dz} = 0.$$

Now it is very easy to calculate the action of the superficial moving electricity if it be assumed to act like an electric current. Each element of the surface will act as if it had an electric $\delta.p$ on it, and the x components of the electro-magnetic potential will evidently be the same as the electrostatic potential, while the y and z components will vanish. Hence—

$$F_c = \frac{\mu ep}{R} \quad G_c = H_c = 0.$$

My assumption is that the complete components are—

$$F = F_c + F_d \qquad G = G_c + G_d \qquad H = H_c + H_d$$

and it is easy to see that they can be put intc the form,

$$F = \frac{\mu ep}{R} + \frac{\mu ep}{6}\left\{ (R^2 - a^2)\frac{d^2}{dx^2}\cdot\frac{1}{R} - \frac{2}{R} \right\}$$

$$G = \frac{\mu ep}{6}(R^2 - a^2)\frac{d^2}{dxdy}\cdot\frac{1}{R}$$

$$H = \frac{\mu ep}{6}(R^2 - a^2)\frac{d^2}{dxdz}\cdot\frac{1}{R}$$

and these satisfy the condition—

$$\frac{dF}{dx} + \frac{dG}{dy} + \frac{dH}{dz} = 0.$$

These may be further simplified by assuming a function—

$$\chi = -\frac{\mu ep}{2}\left(x + a^2\frac{d}{dx}\right)\frac{1}{R}$$

$$F = \frac{\mu ep}{R} + \frac{d\chi}{dx}$$

$$G = \frac{d\chi}{dy}$$

$$H = \frac{d\chi}{dz}$$

We hence easily see that in the general case where the sphere is moving with component velocities $p\ q\ r$, we must take—

$$\chi = -\frac{\mu e}{z}\left\{ px + qy + rz + a^2\left(p\frac{d}{dx} + q\frac{d}{dy} + r\frac{d}{dz}\right)\right\}\frac{1}{R}$$

or calling—

$$p\frac{d}{dx} + q\frac{d}{dy} + r\frac{d}{dz} = \frac{d}{d\theta}.$$

and observing that—

$$p\frac{x}{R} + q\frac{y}{R} + r\frac{z}{R} = \dot{R}$$

we have—

$$\chi = -\frac{\mu e}{2}\left(\dot{R} + a^2\frac{d}{d\theta}\cdot\frac{1}{R}\right)$$

and then we have—

$$F=\frac{\mu ep}{R}+\frac{d\chi}{dx}$$

$$G=\frac{\mu eq}{R}+\frac{d\chi}{dy}$$

$$H=\frac{\mu er}{R}+\frac{d\chi}{dz}$$

From these it appears at once that the magnetic effect of the displacement currents is nil. For the components of the magnetic force α, β, γ, are—

$$\alpha=\frac{dG}{dz}-\frac{dH}{dy}$$

$$\beta=\frac{dH}{dx}-\frac{dF}{dz}$$

$$\gamma=\frac{dF}{dy}-\frac{dG}{dx}$$

and χ disappears from this, and there only remains the magnetic action due to the current that I have assumed to represent the moving superficial electricity. The effect of this is obviously the same as if the whole quantity of electricity were moving at its centre, and this is the same as Mr. Thomson's result (*l.c.* p. 236).

It is to be observed that Mr. Thomson has intentionally omitted the self-induction of these displacement currents on one another, and it may legitimately be omitted when the motion is comparatively slow, but a complete solution of the question would be most interesting.

It may be worth while remarking that no effect except light, has ever yet been traced to the displacement currents assumed by Maxwell, in order to be able to assume all currents to flow in closed circuits. It has not, as far as I am aware, been ever actually demonstrated that open circuits, such as Leyden jar discharges, produce exactly the same effects as closed circuits, and until some such effect of displacement currents is observed, the whole theory of them will be open to question.

XXIII.—ON A NEW FORM OF APPARATUS FOR ESTIMATING AMMONIA IN POTABLE WATERS, BY C. R TICHBORNE, LL.D., F.C.S. &c.

[Read, February 20th, 1882.]

According to the generally accepted method of examining potable waters, the estimation of minute traces of ammonia existing as such, and the ammonia which results from the oxidation of nitrogenous organic matter, are looked upon as being of the greatest importance in arriving at a conclusion as regards the quality of the water. The process may be concisely described as distilling off a third of the water, and estimating the ammonia in the distillate by Nessler's delicate process, which leaves nothing to be desired as regards its accuracy.

As the amount to be determined does not much exceed one part in ten million parts, it is evident that it is necessary to avoid any accidental contamination from atmospheric ammonia. This is particularly the case in chemical laboratories, where ammoniacal solutions are constantly undergoing evaporation, and the air is contaminated with that volatile base.

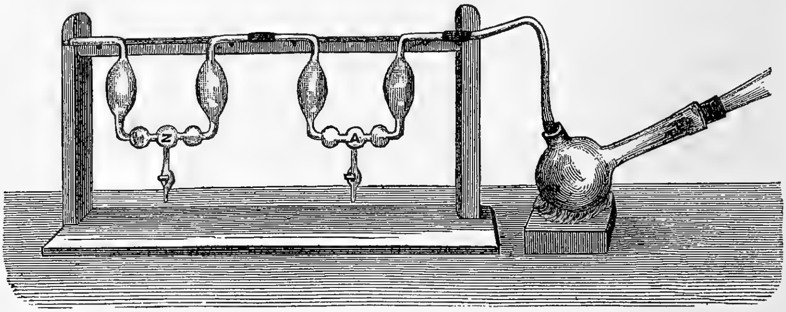
The fact is, of course, well recognised by all expert analysts, and is generally guarded against by the use of a special cupboard or chamber, in which the whole operation can be performed. Such a method is more or less imperfect, because the gas-burner used will itself, under certain conditions, become a source of ammonia. Also, it is evident that a general ammoniacal atmosphere in the adjacent laboratory will find its way into the chamber by the ordinary laws of diffusion.

The capacity of the vapour of water (when in the act of condensing) of absorbing traces of ammonia is something extraordinary, and can only be appreciated by the practical worker.

In distilling potable waters, I was accustomed to work with an ordinary retort and receiver—the latter being provided with a specially-contrived mercurial valve. Now, although this was satisfactory in closing the interior of the retort and receiver from general contact with atmospheric impurities, occasionally a regurgitation would take place, and admitted a little of the laboratory air.

The following arrangement has been lately adopted by myself, and, both as regards simplicity and efficacy, leaves nothing to be desired. It is, in fact, so simple that, to a superficial observer, my communication might at first sight appear superfluous, but the importance of the question involved renders any apology unnecessary.*

At ordinary temperatures very weak solutions of ammoniacal gas (such as we have to deal with in the analysis of potable waters) are fairly permanent; but, in the gaseous conditions, owing to the different tensions of the vapour of water and ammonia, this stability no longer exists. Again, small traces of ammonia in the gaseous condition are instantly absorbed by water in the non-gaseous condition. These are the two equal sources of error to be guarded against in the distillation of ammonia from potable waters, and, bearing these two points in view, I adopted the arrangement figured below.



It consists of a retort fitting into a fairly long-necked receiver, with an india-rubber stopper. The arrangement must be air-tight. The receiver is connected with a bent tube proceeding from its stopper, and connecting it with two bulb tubes of a special form, and marked respectively "A" and "Z." This marking is to prevent any confusion in the hurry of manipulation, as they are exactly the same shape. The bulb tubes are somewhat similar to a flat Liebig's potash bulb, but with two pear-shaped bulbs on each side, to prevent regurgitation of the fluid, and three absorbtion bulbs at the bottom. The centre bulb of

* One of the recent important works upon chemistry, is "Roscoe and Schorlenmaers' Treatise." In their description of the determination of ammonia in potable waters, there is no provision against this fruitful source of error. If the determination were carried on as it is figured at page 252, Vol. I., of that work, the results would be utterly unreliable in any laboratory where other analyses were being performed.

these three is provided with a glass tap for filling and emptying the apparatus.*

The water to be examined is poured into the retort, and one-third distilled over gently, but at a fairly good rate. If operating upon half-a-pint, the operation should take about one hour. The whole apparatus is previously connected together, and the two bulbs are filled with water free from ammonia (*i.e.*, water which has been boiled rapidly in a flask, until it gives no reaction with the Nessler reagent). The bulbs are easily filled by opening the tap, inserting the point of the tap tube into a beaker of the water, and sucking with the breath gently—at the same time, stopping the other end of the bulb tube by the finger.

After the operation is completed, you have the most of the ammonia, if not all, in the receiver, whilst any vapour which might have escaped therefrom is caught in the tube "A;" at the same time, any atmospheric ammonia which enters by regurgitation is caught in the bulb tube "Z." "A" is run into the distillate in the receiver, whilst "Z" is rejected. In practice, it is not necessary that the water in "Z" should be changed for twenty or thirty operations, providing that an increased amount of ammonia is not about in the laboratory atmosphere; but if so, it is desirable to change with each experiment.

If we consider the points that I have dwelt upon as being sources of error, we shall see that this simple apparatus fulfils absolutely the necessary conditions, and that the tube connecting the bulbs "A" and "Z," *contains an atmosphere perfectly neutral as regards ammonia*, because it is the space between two liquids which do not give off ammoniacal gas, and which give off vapour of an equal tension.

I may mention that, on submitting it to experimental proof, the use of an acid in either of the bulb tubes proved a mistake.

It is not necessary to give further details, but I may as well state that in many crucial experiments, I have been in the habit of estimating the amount of ammonia in the receiver, and both bulbs "A" and "Z." The following, as regards Vartry water, will serve as an illustration:—

Distillate in receiver, ...	0·003 per 100,000.
Bulb "A" (nearly), ...	0·001 ,,

Bulb "Z," gave an indication which affected the Nessler, but which was not sufficient to estimate.

* Bulbs of my pattern are made by Messrs. Cette & Co., of London.

XXIV.—ON A NEW ANALYSIS OF THE LUCAN SULPHUR SPA, BY J. EMERSON REYNOLDS, M.D., F.R.S., PROFESSOR OF CHEMISTRY, UNIVERSITY OF DUBLIN.

[Read March 20th, 1882.]

I HAVE the pleasure to lay before the Society the results of a new investigation of the once celebrated Sulphur Spa at Lucan, from which it will appear that we have in the neighbourhood of Dublin a mineral spring of considerable therapeutic value.

The examination of the water was undertaken at the request of the excellent medical officer of the district, Dr. Levinge of Lucan, and, after some preliminary work, I visited the spa on the 10th of February, 1882, when I made the necessary observations at the source of the supply, and collected the samples that I afterwards analysed in the Trinity College Laboratory.

The water is obtained from a small iron pump, which latter is quite close to the bank of the River Liffey and within the demesne of Colonel Vesey, D.L. The learned Dr. John Rutty, in his remarkable book,* published in 1772, states that the spring was discovered in 1758, apparently by "Agmondisham Vesey, Esq., and a little to the N.W. of a chalybeate spring in the neighbourhood, formerly in some repute, but now neglected."

More than a century since the well was "seven feet long, two feet broad and fifteen inches deep, and yields a large supply of water, containing 82 gallons, and when emptied fills again in an hour. The soil about is sandy and limestone." This well is now covered in and some care taken to secure it from surface drainage, the water being lifted by a small pump as already stated.

The spring still affords a good supply, and doubtless is derived from the limestone shales found by the Geological Survey in the immediate neighbourhood.

The water as it issued after continued pumping had a strong smell of sulphuretted hydrogen, and was slightly opalescent, as are most other sulphur waters. Its colour, as observed through a column of 250 centimeters, was greenish gray, indicating a minute

* "An Essay towards a Natural History of the County Dublin, accommodated to the noble designs of the Dublin Society" (now Royal Dublin Society).

quantity of metallic sulphide in suspension, probably derived from the material of the pump.

The taste of the sample was that common to all sulphuretted waters containing little saline matter, but was moderately brisk to the palate, while the reaction to test paper was distinctly alkaline, more especially after drying the paper.

The temperature of the water as it issued from the pump was 7° C. (=46° F.), that of the surrounding air being 12·2° C. (=54 F.)

The analysis at the spring proved the presence of free carbon dioxide as well as sulphuretted hydrogen; also of alkaline sulphydrate and ready-formed sulphuric acid. Determinations of these were made or commenced on the spot. But neither at the spring nor in the laboratory did I detect any traces of thiosulphate in the fresh water, though the latter was formed in small quantity by secondary change on standing.

The water when examined with a view to its sanitary condition did not afford evidence of sewage contamination, and was free from nitrites, though traces of nitrates were found as a matter of course.

The following Table (I.) contains the statement of the results of the determinations of the several constituents in 100,000 parts of the water (*i.e.* centigrams per liter.)

TABLE I.

LUCAN SULPHUR SPA.

Contents in parts per 100,000.

Calcium,	3·272
Magnesium,	1·433
Sodium,	13·495
Potassium,	1·675
Lithium,	traces.
Alumina (with traces of iron),	1·008
Carbonic acid, combined (CO_3),	38·101
Sulphuric acid, „ (SO_4),	5·534
Chlorine (with traces of iodine),	4·830
Sulphur, as alkaline sulphydrate,	0·380
Silica,	1·105
Gases in solution—cubic centimeters per liter.	
Sulphuretted hydrogen,	8·17
Carbon dioxide,	41·06

In the next Table (II.) I give the composition of the water in the usual form, having distributed the bases and acids according to the well-known plan, and stated the quantity of each body in grains per imperial gallon (*i.e.* 70,000 grains.)

TABLE II.

LUCAN SULPHUR SPA.

Constituents stated in grains, per imperial gallon of 70,000 *grains.*

Calcium carbonate,	1·690
Magnesium carbonate,	3·605
Calcium sulphate,	5·487
Sodium bicarbonate (N_aHCO_3)	28·275
Sodium chloride,	3·829
Sodium sulphydrate,	0·451
Potassium chloride,	2·239
Lithium carbonate,	traces.
Alumina (with traces of iron),	0·756
Silica,	0·773
Gases in solution—cubic centimeters per liter.	
Sulphuretted hydrogen,	8·17
Carbon dioxide,	41·06

As my results are materially different from those recently obtained by Dr. Cameron,* I was led to examine some of the older references to this water, in order to ascertain whether its present markedly alkaline condition has always been one of its chief characters.

Dr. Rutty, in the work already referred to, states (at page 203) that a gallon of the water afforded not only sulphuretted hydrogen gas, but 30 grains of solid residue, having a saline and highly alkaline taste, which "excited an ebullition with spirit of vitriol, soon turned of a bright green with syrup of violets, and of an orange colour and red with solution of mercury corrosive in water, and smelt pungent when rubbed with sal-ammoniac; all concurring evidences of an alkaline salt," *i.e.*, an alkaline carbonate. Thus the alkaline character of the water was distinctly recognised at least 110 years ago.

Very similar statements occur in an interesting paper published in 1795,† by an "English physician," whose name is not given; hence 25 years later it possessed the same characters.

* Medical Press and Circular: March 1, 1882, p. 196.

† See vol. xxii., 2, of Medical Tracts in the Library of the King and Queen's College of Physicians, Dublin.

Again, I find that the late Dr. William Higgins, in 1822, recognised the true character of this water, and even made a rough estimation of the amount of sodium carbonate obtainable from it.* Two gallons of the water afforded him 70 grains of "crystallized carbonate of soda," or 35 grains per gallon. This is equivalent to 18·3 grains per gallon of the bicarbonate. This estimation was necessarily but a rough approximation.

These results are of special interest, as serving to show that the spring has preserved its main characters for more than a century.

Amongst the pamphlets relating to the Lucan Spa is one which was written in 1818 by Dr. Heron of Lucan, and contains this interesting passage:—"It may appear strange from the analysis of Lucan water that so small a quantity of the active material as appears to be contained in the water should produce such beneficial effects on the constitution, as we daily witness in those who go to Lucan apparently on the verge of the grave, but whose strength and vigour become so rapidly re-established as to give just reason for the idea of some unknown agent of great activity being diffused through the spring which has resisted our chemical researches." Can it be that the alkaline sulphydrate and traces of lithium found in the water contribute to the effects recorded by this observer?

Having determined the nature of the Lucan water it seemed desirable to compare it with the important sulphur spa at Lisdoonvarna, county Clare. Such a comparison has been facilitated by the comparatively recent publication of a careful analysis of the water referred to by Messrs. Studdert and Plunkett.† On comparing the analyses it appears that the waters agree in general characters—that is to say both are sulphuretted and alkaline spas—that of Lisdoonvarna containing 5·55 cubic centimeters per liter of sulphuretted hydrogen, and the equivalent of only 11·35 grains of sodium bicarbonate, while the traces of lithium were found in it—which can be detected in almost any natural water with the aid of the spectroscope.

It is evident, then, that the Lucan sulphur spa is very nearly double the average strength of the water of Lisdoonvarna.

* See Lucas's Topographical Dictionary of Ireland, under "Lucan."

† Royal Irish Academy Proceedings. Vol. ii., s.s. page 91.

I know that the Lisdoonvarna sulphur spa has proved a most useful aid to general medical treatment, and that many eminent physicians entertain a high opinion of its efficacy but it is well that the medical profession in Dublin should know that a spa of superior strength and quality is to be had nearer home. I therefore hope that when the Dublin and Lucan steam tramway shall have been completed, the increased facility of access, and the judicious enterprise of local proprietors in providing for the comfort and amusement of visitors, will lead to the renewed prosperity of the attractive district of Lucan, once so famous as a health resort.

XXV.—ON THE MODE OF OCCURRENCE AND WINNING OF GOLD IN IRELAND, BY GERRARD A. KINAHAN. With PLATES XX. and XXI.

[Read March 20th, 1882.]

OF recent years improvements in metallurgical processes have rendered the production of silver a much cheaper operation than formerly, and as a necessary consequence, combined with an increase in the supply from other sources, that metal has deteriorated materially in value. This has increased the appreciation of gold, and rendered the sources from which it may be derived more worthy of consideration.

Attention has been directed to the more productive auriferous districts over the world; but although these, and the gold fields of Great Britain, have been described, no special account, so far as I can learn, has been given, in recent years, of the occurrence of gold in Ireland. I have, therefore, ventured to lay before the Society the following epitome compiled from the various published sources, and have endeavoured to bring the subject down to the present date.

Introductory Remarks.

In very remote times, gold was probably a production of Ireland, because in the annals numerous mention of this metal is to be found,* and in recent years the quantities of golden ornaments and vessels that have been exhumed from the bogs and prehistoric structures, would seem to strengthen this supposition.

Of these discoveries, one of the most remarkable is that in the Bog of Cullen, on the borders of the counties of Tipperary and Limerick, where not only golden vessels and ornaments, but also the crucibles, ladles, and other instruments, necessary for the working of that metal, have been found under a considerable thickness of peat. Of the finds in this bog, Vallancey gives an

* See Simon's Irish Coins, page 2, and Wilde's Catalogue of the Antiquities of Gold in the Museum, R.I.A., page 3.

extensive list of those discovered before his time * (1804). Concerning this place he makes the following observations:—

"It is remarkable that the antiquities were found *under the wood;* for that was removed at about six feet depth, and some of them were found very deep; that is near the natural soil on which the bog was formed. It was apparently a manufactory situated in a wood—in a valley—for the convenience of fuel for smelting. This wood had been blown down, and formed the bog in which these things had been found. A stratum of earthy bog had formed on this bog, in which grew another wood, which having been blown down like the former, had formed the upper bog of six feet above it."

This depth of peat probably represents an age since the relics were deposited, of between 2,000 and 3,000 years.†

Of other finds in later years some of the largest recorded seem to have been those at the ancient fords on the Shannon, from which they have been exhumed during the excavations for the improvement of the navigation.

In the ancient annals there is a record that may fix the date of the first working of gold in Ireland. Thus, in the Annals of the Four Masters, we find during the reign of Tighernmas, in the year A.M. 3656, the following entry:—

"It was by Tighernmas also that gold was first smelted in Ireland in Foithre-Airthir-Liffe. (It was) Uchadan, an artificer of the Feara-Cualann, that smelted it. It was by him that goblets and brooches were first covered with gold and silver in Ireland."‡

As a proof that Ireland, in early historic years, was rich in gold, Colonel Vallancey quotes the following passage from the history of Caen in Normandy, by M. Delarue:—

"The exchequer (*i.e.* of Caen) acquired very great consequence and extent when our Dukes became masters of Anjou, Poitou, Aquitane, the

* See "Collectanea de Rebus Hibernicis," by Colonel Charles Vallancey, vol. vi.; also "Manners and Customs of the Ancient Irish," by Eugene O'Curry, vol. iii., page 205 (lecture xxix.)

† See "Geology of Ireland," by G. Henry Kinahan, page 273.

‡ This is also recorded in the book of Leacan. Keating in his History of Ireland gives the date as A.M. 2816, and states that "this Tighernmas was the first who discovered gold ore in Ireland." The Leinster people were formerly called Laighnigh-an-Oir, or the Lagenians of the gold, "because it was in their country that gold was first discovered in Erinn." Foithre-aithir-Liffe was the main ridge of the Wicklow Mountains.

city of Caen was then the seat of the Government, not only of those provinces, but also of Great Britain. The exchequer of England was annually exhausted to fill the coffers of that of Caen, and according to the registers kept in the Tower at London, we find that the treasury of Caen received in one year, 23,730 marcs of silver sent by the treasury of London, besides 400 marcs of silver and 200 ounces of gold sent by that of Ireland—an enormous sum of money for those times."

Giraldus Cambrensis (Gerald Barry), who died about A.D. 1224, also states that Ireland abounded in gold.

The Irish for gold is *or*, which in the Anglicized names is corrupted into *ore*; the occurrence of this in some names of places in Ireland shows that these places formerly were connected with gold in some form or another, though many evidently refer rather to the worked metal than to its occurrence native.*

The following names, however, may refer to the occurrence native of the gold:—

Slieve-an-ore (Mountain of the Gold) near Feakle, Co. Clare: this name is also found in other parts of Ireland.†

Tullynore (Tully-an-ore) (Little Hill of the Gold), Down.

Coom-an-ore (Hollow of the Gold), between Bantry and Dunmanway, Co. Cork.

Lug-an-ore (Hollow of the Gold), near Clonmel, Tipperary.

Glan-an-ore (Glen of the Gold), Co. Cork.

The localities from which gold was to be obtained formerly seem to have been forgotten during the wars that from time to time troubled this Island; for it was not until many years after that we find a suggestion as to the occurrence of it; and not till recent years that any attempt was made to seek for it. Although the early Christians had abundance of gold, there are no records to show that gold mines were known in this country during the Christian Era.

Gold "in Situ" in Ireland.

The small quantities of gold that have been found in Ireland in recent years, seem to have been procured principally from alluvial deposits, or, what in California would be technically

* The word *ore* does not always signify gold. (See Joyce's "Irish Names of Places," second series, page 344.)

† Slieve-an-Aur or Slieve-an-Aura (Co. Antrim), now spelled Slieve-an-Orra (where gold has been found, see page 5), may have the same meaning.

termed, "placer mines." While gold *in situ* (*i.e.* in the original rock or matrix) even in minute quantities, is up to the present of rare occurrence, and few localities have been recorded. Of these may be mentioned:—

A quartz vein, in the Cambrian rocks on Bray Head, Co. Wicklow, which within the past few months has been proved auriferous by Mr. Francis Codd, at the Royal College of Science. This occurrence is of special interest, as it appears to be the first record of an *auriferous quartz vein* in Ireland. The rocks in which this vein occurs are green grits, and slates, across the strike of which it cuts at angle of about 60°. There would seem to be some similarity between these rocks and those of Merionethshire, where gold has been worked near Dolgelly and Barmouth.

The late Sir Richard Griffith, in his list of mineral localities in Ireland, states that the gossan of the Dhurode copper lode at Carrigacat,* on the south shore of Dunmanus Bay, is auriferous (Cork, Ordnance Survey of Ireland, six-inch maps, sheet 147.)

The pyrites of the Ovoca (co. Wicklow) mineral channel, has long been known to contain traces of gold, especially that of Ballymurtagh, Cronebane, and Connary. At Ballymurtagh the gossan is the richest part, but it is also found in the pyrites lode; it is also stated to occur in the ochre that separates from the drainage waters of these mines.

At Upper Cronebane and Connary there appears to have been a richer deposit, from which the gold was extracted, as M. Charles Coquebert, writing, about 1794, a description of these mines in the "Journal des Mines," No. XVI., states that at Liverpool, they extracted by liquation, from this pyrites, "a certain proportion of silver, and this silver contains 0·01146 of gold."†

In some parts of the lode at Ballymurtagh, Upper Cronebane, and Connary, an ore is found called "Kilmacooite," which has been described as "a peculiar combination of sphalerite, argen-

* There are specimens in the College of Science Museum from this locality. These specimens consist of "auriferous" gossan associated with hard white crystalline quartz containing "vugs" filled with yellow ochre.

† I am informed by Captain Argall that when the Wicklow pyrites was used extensively in England, from the pyrites ash an auriferous silver was extracted at St. Helens by a liquid process, which was worth from 8*s.* to 10*s.* per ounce; any Wicklow ore was used.

tiferous galena, iron and copper pyrites, and antimony glance, with a trace of gold."

M. Charles Coquebert speaks of this as follows:—

"At Connary, very near the high road, in the part of the vein which trends towards the North East, this vein enlarges much towards the surface of the earth, and contains a galena having a steely grain mixed with killas, very difficult to smelt, which produces about 25 per cent. of lead containing one and a half ounces of silver per hundredweight. The top of the vein produces in many places a substance like ochre, which contains about one-half per cent. of silver and a little gold."

Speaking of Upper Cronebane and Connary, Weaver evidently refers to this ochreous deposit in his description:—

"A brown indurated oxide of iron in the upper part of a metalliferous bed, in the higher grounds of Cronebane, containing minutely disseminated native silver which contained thirty grains of gold to the ounce—that is about six and one-fourth per cent."*

And a similar deposit was worked at Connary, about 1856, that contained from six to twelve ounces of silver and half an ounce of gold in the ton of material.

"*Placer*" *Gold.*

Of "placer" gold there are several records, while it is probable that the sands of many of our rivers, if carefully washed, would yield, if not traces of gold, other metals and minerals equally if not more interesting.

Gerard Boate, in his "Natural History of Ireland," written A.D. 1652, mentions that gold had been found in the sands of the Moyola river, which rises on the borders of Tyrone and Londonderry, and flows into the north-west corner of Lough Neagh. The geological structure of the country about the head-waters appears to be Silurian slate (mica slate), with some igneous rocks.

Gold is reported to have been found, prior to 1820, in the sands of the streams flowing from Slieve-an-Orra (Antrim, sheet 19) into

* He mentions that the plate of several of the county families was made of this rich alloy. In the parish church (Castlemacadam) the chalice belonging to the communion plate is stated to have been made of the same. On this piece is the following inscription:—

"The produce of Cronebane mines and gift of ye gentlemen of ye Company of ye said mines, to ye parish church of Castle M'Adam, A.D. 1753."

the Glendun river, which enters the sea at Cushendun.* The summit of Slieve-an-Orra is composed of basalt, but on the north and east slopes mesozoic rocks crop out, which rest on Silurian slate. From these older rocks it is to be supposed the gold originally came.

It has been reported that gold has been found near Ballinascorney Gap, county Dublin, and that the peasants from that neighbourhood have brought it in quills into Dublin. Small pieces have been picked up from the Dodder sands above Rathfarnham; and some years ago two small nuggets, each attached to quartz, were picked up in Stephen's Green, from gravel brought from that river. Another reputed locality is on the hills of the barony of St. Mullin's, county Carlow, where an old man is said to have obtained gold. Unsuccessful trials have been made here by Mr. Kavanagh of Borris.†

Small specks of gold were observed in a typical "black sand" from near Greystones, county Wicklow. It is possible a bed of this sand lies below the level of the beach hereabouts, as north of this a thin layer was seen on the top of the marl, exposed in a sinking made in connexion with the railway. Another locality where traces of gold have been observed, is the gravel of the Ovoca river, near Newbridge.

Weaver in his explorations found small quantities in the Ballycreen stream, also in Ballinagappoge (in the stream called the Mucklagh brook), both tributaries of the Ow, which unwater the south and west slopes of Croghan Moira. Mr. F. Acheson, I believe, found gold in the Ow river, above Ballymanus Bridge; while in Griffith's list of mineral localities, Killacloran, near Aughrim, is given as a gold locality. It has also been found at Ballycoog ford.

The principal Irish placer mines worked during recent years occur along the tributary streams of the Daragh water or Aughrim

* About 1825, it was proposed by the Glenarm and Antrim Mining Association to work this river.

† In 1863 there was a rumour that a 6lb. nugget, besides many smaller, were found at Crossmolina, county Mayo. In the list of exhibits at the Exhibition of Irish Manufactures in 1844 (see Proceedings Roy. Dub. Soc., Vol. 80), specimens of native gold and silver are mentioned as belonging to the Mining Company of Ireland. Where the gold came from cannot be ascertained; it is reported to have weighed 40 oz.

river, which itself is a tributary of the Ovoca, joining the latter at the lower "Meeting of the Waters," near Woodenbridge. These tributaries unwater the north and north-eastern slopes, valleys, and associated spurs of Croghan Kinshelagh. To the north-west, gold in very minute quantities has been found in the Ballythomas brook. This and the streams to the west and south were explored by the peasants, who probably washed only the upper river gravels; so that, as there is a deep deposit of drift in all the valleys, it is very possible, if a sinking had been made to the rock, gold in greater quantities would have been obtained.

Croghan Kinshelagh, *Historic Notes.*

It does not appear that there were any ancient gold diggings in this locality. It has been reported, however, that before the Government instituted workings here, during the last century, the ground in places had the appearance of having been previously worked.

The following early historical notes have been taken principally from the letters of Lloyd and Mills to the Royal Society, and the published reports of the directors (Weaver, Mills, and King) to the Government.

About 1765 the first recorded piece of gold was found here, by a man crossing the brook (Ballinvally); it was about the size of the head of a brass nail. This set many people looking for it, but it appears they were very unsuccessful, as they soon abandoned the search. However, a local schoolmaster, named Dunahoo, in 1770, used to seek after it in the early mornings, and he told his neighbours, amongst them Mr Graham of Ballycoog House, that gold abounded in some of the valleys. About the same time a piece was found by a boy, named John Byrne, when fishing; and it was also stated that some Dublin jeweller about this time obtained four or five ounces of gold annually for eleven or twelve years from a peasant of the vicinity.

After September, 1795, the wealth of the stream* between Ballinvally and Ballinasilloge became generally credited in the neighbourhood. One report states it was owing to a man finding a piece half-an-ounce in weight, while another is that a lump weighing

* This stream was then called "Aughatinavought." This name is now quite forgotten locally, having been supplanted by that of "Gold Mine river." (See Map, plate xxi.)

$1\frac{1}{2}$ pounds had been found in the upper part of one of the rivers but, as it was supposed to be copper, it remained for several years in the possession of a family named Byrne (who used it as a weight). However, about this time it was sold to an itinerant tinker, who again sold it to a jeweller in Capel-street, Dublin.

When the riches to be obtained from the valley became known, the peasants congregated from the surrounding districts to take part in the spoil, and "over 300 women, besides great numbers of men and boys, were engaged in the work." They continued in undisturbed possession at Ballinvally for about six weeks, obtaining, according to Mills, who wrote immediately after they ceased, about £3,000 (Irish) of gold (or as it sold for £3 15*s.* per oz., about 800 oz.). Mr. Graham, however, estimated it as £10,000 worth, or 2,666 ounces.

The work being quite novel, the peasants' method of extracting the gold was extremely rude, and after rain metallic specks were to be seen on the waste heaps, which subsequently afforded a profit on re-washing. They found that the richest place was from 200 yards below the Ballinasilloge ford to 150 yards above it. The largest nugget* they obtained is recorded as having weighed 20 oz. 2 dwt. 21 grs., but Mills mentions one as having been found that weighed 22 oz., others of 5 oz., and of 2 oz. 17 dwt.

In October (1795) the Government sent the Kildare Militia to occupy the place, "when the great concourse of people, who were busily engaged in endeavouring to procure a share of the treasure, immediately desisted from their labour and peaceably retired," or migrated to explore other streams.

The Government having obtained an Act of the Parliament of Ireland,† started regular streaming works in the August of the following year, 1796, under Messrs. King, Weaver, and Mills, who were directed—

"In the first instance, to endeavour to collect all the gold deposited, and thereby to remove every temptation for the assembling of mobs,

* This was weighed by William Molesworth, who found it to have the remarkably low specific gravity of 12 although worth £4 per oz.; he found it full of cavities and pores. Kirwan found the specific gravity of another piece to be 13.

† This was an Act "To enable the Lords Commissioners of His Majesty's Treasury to conduct the workings of a gold mine in the county of Wicklow," which received the Royal assent, 24th April, 1797.

whose numbers had before that time increased to a very alarming degree.

"Secondly.—To produce, if possible, a profit from the workings.

"Thirdly.—To ascertain whether the works should be proceeded upon or abandoned."

To carry out these instructions they proceeded to rewash the clay and gravel which "had been rudely washed by the populace," and to continue the works after the gold wherever it was found, till the depth of covering "had become so thick as to preclude the hope of gain from individual trials, conducted without order or regularity."

In the meantime the natives, who had been driven from their diggings in Ballinvally, were exploring the neighbouring brooks but any discoveries they made they endeavoured to keep secret because whenever the directors heard of one, they proceeded thither and instituted trials. These were, however, all abandoned after a short time, as none of the places appeared as favourable as the Ballinvally stream.

These stream operations were continued until May, 1798, when the labourers having deserted to join the insurrection, the mining plant was carried into Rathdrum to assist in fortifying a barrack, after which the insurgents burned the miners' huts.

Up to this period the gold obtained amounted to 555 oz., 17 dwt., $22\frac{1}{4}$ grs., which produced £2,146 15*s.*, and had cost £1,815 16*s.* 5*d.*

The gold is described as of a bright yellow colour and very malleable, about 22 carats fine; the alloy being silver with a little copper and iron. It had a specific gravity of from 12, that of the largest piece obtained, to 16·5, that of the fine grains; the low specific gravity being due to its porosity, some of the cavities containing ferric oxide and quartz. At that time its marketable value was £4 per oz.

[TABLE

ANALYSES OF WICKLOW GOLD.*

—	Gold.	Silver.	Iron.	Copper.	Silica.	Total.	Specific Gravity.	Authority.
A	$22\frac{58}{101}$	$1\frac{43}{101}$	—	—	—	24	12	Weaver's Assay.
B	$21\frac{6}{8}$	$1\frac{7}{8}$	$\frac{3}{8}$		—	24	—	Alchorne (Mint Master).
C	92·32	6·17	0·78	—	—	99·27	16·342	William Mallet.
D	91·01	8·85	—	—	0·14	100·00	14·34 15·07	D. Forbes.
E	89·00	8·10	2·1	trace.	—	99·20	—	Scott.

The low specific gravity is due to the porosity of the gold; A, was of a large nugget—C, small grains.

COMPARATIVE ANALYSES OF SOME QUEENSLAND GOLD.

Gold.	Silver.	Iron.	Copper.	Lead.	Bismuth.	Total.	Authority.
89·920	9·688	0·070	0·128	0·026	None.	99·832	Percy and Smith.
92·805	6·774	0·014	0·048	0·048	Trace.	99·684	Smith.

"The gold was found accompanied by other metallic substances dispersed through a stratum composed of clay, sand, gravel and fragments of rock, and covered by soil, which sometimes attained to a very considerable depth, from twenty to fifty feet, in the bed and banks of the different streams. In every instance where gold" was found there was "also found fragments of *magnetic iron ore* and *quartz*, containing *chlorite*, *iron ochre* and *martial pyrites*, attended, more particularly at the works at Ballinvally, with *specular iron ore*, *brown* and *red ironstone*, *tinstone crystals*, *wolfram*, and grey ore of *manganese*." Tinstone was also found in Monaglogh and Coolbawn.

In some specimens quartz was adherent to the gold, the magnetite, and to the wolfram; and also the gold sometimes was found incorporated with wolfram and ochre.

Mr. William Mallet has since added the following minerals to these lists:—

Galena, titanite, calcopyrite, molybdenite, with the gems sapphire, topaz, zircon, and spinelle, besides some minute specks of a white metal that appeared to be platinum. It may also be remarked that on washing the sand, numerous little white

* For Welsh gold, see "Phil. Mag." (4) xxxiv., 331 and xxxviii., 321. Watts' Dict. 2nd Supp., 572.

spherical balls are found; they are evidently altered grains of shot, probably occurring as carbonate of lead.

In September, 1800, when the times became a little settled mining operations were resumed, and in addition to the streamings extensive exploration works were undertaken in 1802. A level (to prove the quartz veins in depth) was driven 178 fathoms into the mountain, from above that place, on the Ballinvally stream, where the highest particles of gold were obtained (although unaccompanied here by the usually associated minerals), and where the quartz veins appeared most numerous, but although fifty or sixty quartz veins were crossed not a particle of gold was obtained. Furthermore, thousands of fathoms of open casts were cut along the slopes of the mountain, and "the mineral substances were subjected to the operations both of fire and of amalgamation, but in no instance was a particle of gold elicited from them, either by the one or the other process. So unsatisfactory a result led to the persuasion that the gold formed no part of the veins which appear in the mountain. The same conclusion seems to apply to the tinstone, wolfram, and manganese, in discovering which the mining operations equally failed."

In 1803, after the directors' unfavourable report, Government abandoned the enterprise; for although streaming works had proved profitable, the explorations had entailed a heavy loss. The total quantity of gold obtained by the Government amounted to 944 oz., 4 dwt. 15 grains, which produced £3,675 7*s.* 11½*d.**

Since 1803 this and several of the neighbouring streams have been worked systematically at intervals with varying success, but on the whole unprofitably. The peasants, between times, working the streams apparently with more satisfactory results. The records of all these workings are, however, scattered and scanty.

When Government abandoned their active mining operations, they left for a time a company of infantry to guard the place; but after these were removed the people resumed their search after the precious metal; and it has been estimated that about £2,000 worth of gold was sold annually by them in Dublin; others have estimated the whole produce as worth £20,000 during the time they continued working.

About the year 1839 or 1840 Government granted a lease for

* The total expenditure is stated to have been £6,907 14*s.* 2¾*d.*

21 years, to Messrs. Crockford and Co., of all the gold that might be picked up. Extensive trenches were cut at right angles to the Ballinvally stream, and works undertaken in Moneyteige, besides working the Ballintemple stream; about fifty men were employed, but the workings were only continued for about four months—£1,800 worth of gold having been obtained. During these workings an 11 oz. nugget was obtained at Ballinasilloge, and from Ballintemple nuggets weighing 4 oz. 12 dwt. 10 grs. and 4 dwt. have been recorded.

In 1862* the Carysfort Mining Company obtained the gold royalties† of the district, and instituted extensive trials. They "costeened" the surface of the mountain to a considerable extent, while they collected, crushed, and examined the quartz of the district. "Some of the more promising lodes of quartz" were "pierced by shafts a couple of fathoms deep," but without finding a vein of gold-bearing stone. The researches which were made "into the deposits in the valley showed a wide distribution of the particles of gold. Of those particles which could be called nuggets, the larger were found at the upper parts of the streams towards their sources, and as they descended the streams the particles became more minute." This was not an "absolute rule, but was generally the case." The largest nugget found weighed 320 grains.

This company ceased operations after gold about 1865, and had obtained £203 6*s.* worth, after having sunk shafts upon and examined almost every known lode in the neighbourhood, without finding any gold in its original matrix or vein.

At the present time the royalty of the district is held by Mr. F. Acheson, who has been working for several years past, but discontinued mining operations a short time since. In the works carried on under him the richest deposit was found in the "Red hole," about 500 yards above the Ballinasilloge ford, on the old Arklow road.

* About 1849 an attempt was made by a Mr. Collett to work the district, but no mining operations seem to have been undertaken. During the working of the peasants in 1856, two nuggets were found, one weighed 6 oz. worth £30, the other 24 oz. worth £100.

† This Company was established early in 1859 to work the lodes of the district, but did not obtain the gold royalties till 1862. It appears that in 1860 Colonel Butler had obtained the gold royalties of 70,000 acres of this district, and Mr. Bullen the gold royalties of the vale of Ovoca to Arklow, but in neither case were active operations undertaken. Henwood states that they obtained 85 oz. altogether, but gives the period of working, 1857–1862. In the following table the quantities in parentheses are calculated from the value of the gold at the time.

TABLE OF WORKINGS AT CROGHAN KINSHELAGH.

—	Duration of Works.	Number of Ounces	Value.	Largest Nuggets.	Remarks, Authorities, &c.
Peasants.	For 6 weeks to 15th Oct., 1795.	Estimated 800 oz. to 2,666 oz.	£3,000 to £10,000.	oz. dwt. grs. 22 0 0 20 2 21 5 0 0 2 17 0	Mills. R. Molesworth. Mills.
Government Workings.	12th Aug., 1796, to 26th May, 1798.	oz. dwt. grs. 555 17 $22\frac{1}{4}$	£2,146 15s.	18 ounces. 9 ,, 7 ,, $2\frac{1}{2}$,,	Reports to Government by Mills, Weaver, and King.
	8th Sept., 1800, to 24th June, 1801.	oz. dwt. grs. 43 9 10	£ s. d. 112 14 $11\frac{1}{2}$		
	June, 1801, to 1803.	oz. dwt. grs. 344 17 $6\frac{3}{4}$	£1,415 18s.	1,507 grs.	R. D. S. nugget.
Peasants.	To 1839.	(5,000 oz.)	£20,000	$4\frac{1}{2}$ ounces.	Estimated in 1840.
Crockford's Company.	4 months (1840).	(600 oz.)	£1,800	11 ounces.	Return to Woods and Forests.
Peasants.	To 1857.	(?)	(?)	24 oz. & 6 oz.	Hugh M'Dermott, Arklow.
Carysfort Mining Co.	1862 to 1866.	(oz. dwt. grs. 52 11 5)	£203 6s.	320 grains. 105 ,, 83 ,,	Geological Society. Directors' Report.
Recent workings.	1876 to 1879.	oz. dwt. grs. 14 3 0	£60.	(?)	Mineral Statistics.

Total produce since 1795 may be estimated at between 9,390 ounces and 7,440 ounces; value between £36,185 and £28,855.

Physiography of Croghan Kinshelagh.

Croghan Kinshelagh may be regarded as the central portion and summit of a rather isolated tract of high ground, that rises to an elevation of 1,987 feet above the Ordnance datum, on the borders of the counties of Wicklow and Wexford, which sends out spurs and knolls from the main mass, each bearing a distinctive local name. (See Map Plate xxi., and Section Plate xx., Fig. 2.)

The body of the mountain is composed of sub-metamorphic Lower Silurian slates (argillite or chloritic and talcose clay slate), which strike generally about N. 45° E., and dip at about 70° to the S.E. Through these sedimentary rocks are various eruptive

rocks, of which, broadly speaking, those in the south-west spur are plutonic, and those to the north volcanic. In many places both the sedimentary rocks and eruptive dykes have undergone a peculiar change or decomposition, being altered into soft friable red and yellow clays, but in which the original structure is still apparent. This is evidently a chemical metamorphosis, and appears to have been either an impregnation of the rocks with iron salts, or a decomposition of those already present, probably a combination or alternation of both.

The superficial deposits consist of various depths of meteoric or local drift, the result of the disintegration of the upper portions of the underlying rocks; over this in places a thin covering of peat, while in the valleys there are old river gravels and alluvial deposits.

The proved auriferous valleys lie to the north and north-east of the summit of the mountain, the principal and central one at the base of the eastward slope of the northern spur, which comprises the hills of Moneyteige (1,892 feet) and Ballycoog (1,169 feet), in the rocks of which are lodes of magnetite, pyrite, calcopyrite, and galena.

The Occurrence of the Auriferous Gravels.

In the south Wicklow district the valleys that have been proved auriferous have all very similar physical and geological characters; they are comparatively narrow, with very steep and abrupt sides, on which there is usually only a scanty covering of soil. The bottom of the valleys are comparatively level, formed of alluvial deposits and local drift, that appears to have been derived from the wasting away of the sides of the original chasm in the rock. These general features become modified on ascending the streams. (See Plate xx., Fig. 1.)

The gold has been found principally in an ancient river gravel associated with the minerals previously mentioned, which make up the "black sand" resting on the "bed rock" at the bottom of the old valley and under the local drift, in which, and the more recent river deposits, it is distributed but sparingly. The auriferous deposit is richest at the lower portions, especially

where large stones occur, under and around which a very rich accumulation was often found,* as if due to the eddies that were produced by them in the ancient stream. On the bed rock the gold almost invariably occurs in "strings" or "leads," which form rich accumulations at the large stones mentioned above, and also in the hollows that are formed at the intersections of joints and breaks; and Kirwan has remarked that the deposit was most productive in the more level parts of the valleys, at the angles of the streams, and especially at the confluence of the streams, and also where the stream crosses the strike of the rocks.

The Auriferous Streams.

The following streams are those that have been systematically searched in this district. (See Map Plate xxi.)

The Ballintemple stream falls into the Daragh water on its right bank, about a mile north-west of Woodenbridge, it was worked first by Crockford and Co., and subsequently by the Carysfort Company.† Besides small gold, numerous small nuggets were found. The waste heaps are traceable from the Aughrim valley, up to a short distance above the "Bride's Well"

The Gold Mine River, however, is the principal auriferous stream, and enters the Daragh water at Woodenbridge; about a mile S.W. from which this stream bifurcates; and, for convenience in describing its branches, we will adopt the names applied by Weaver to them respectively, Western and Eastern or principal, auriferous streams. Below their junction the deep gravels of these rivers have not been explored.

The Western Auriferous stream or "Gold Mine River," is formed by the junction of three rivulets (draining the north-eastern slopes

* This was so well recognized by the old diggers, that if they came on one towards night they would watch it till morning, fearing lest it might be robbed. The usual large stones in these valleys are the Greenstones from the adjoining hills. Besides the riches on the bed rock, in one place a thin seam of clay occurred in the gravel, above which there was a rich accumulation of "black sand," besides that found below it.

† It is an interesting fact that the gravels of many of these streams, after being allowed to rest for a time, paid for re-washing. The machine usually employed was "The Long Tom," and it was no uncommon thing for the local diggers to pan the sand from the mouth of the Company's Tom, and obtain a fair return from it—one notorious digger, Regan, obtaining £5 worth on one occasion. The machine used at the Government workings is described in the "Transactions Royal Dublin Society," Vol. II., and there is an interesting picture of the workings in the Museum.

of Croghan Kinshelagh), a short distance above the bridge of Ballinagore. At their confluence, Weaver obtained some small gold, but not accompanied by the usually associated minerals. Above this he drove a level 178 fathoms to the north-west to prove the quartz veins in depth, while, in continuation of the stream works, an open cut was carried up the slope of the hill towards the south-west. At Ballinagore bridge he made an open cut on the right bank of the stream, that proceeded about a mile to the south-east, while another cut was made about 600 yards lower down, at the "Red Hole," on the left bank of the stream, that proved the ground to the north-west, as far as the top of the ridge bounding Ballinasilloge and Moneytiege. The river here is called in Weaver's Memoir the Ballinvally stream; it was formerly *Aughatinavought.* It was proved continuously along this part of its course, but except the little gold found above the bridge, no gold was found by Weaver above the Red Hole. From this, for about 400 yards down the stream, the richness of the deposit must have been very great, when we remember that it was here the peasants worked, while that subsequently Weaver found it the most productive working; also, that since then it has been worked by Crockford and the Carysfort Company, and the upper portion, of late years, by Mr. F. Acheson.

Lower down this stream, the remains of old workings are to be found at intervals, to within about 400 yards of the junction with the eastern auriferous stream. In a small tributary that enters on the left bank flowing from Ballykillageer (old name, Aughanarragid,* or the Silver or Money brook), the old workings extend up to the old Arklow road.

The Coolbawn stream flows north from Croghan Kinshelagh, between Coolbawn and Moneyteige, by Kilpipe, to join the Daragh water at Annacurragh. In this stream, at the confluence of its upper branches, Weaver found a $2\frac{1}{2}$ ounce nugget—the largest he got anywhere except in Ballinvally. Here, also, he found some tinstone, and one of his trenches was opened up the western branch, and nearly round the summit of Croghan, without finding any gold. Subsequently, the eastern branch has been profitably worked. This stream does not appear to have been worked

* This name—pronounced as spelled above—is still used by some of the older inhabitants.

for more than about 500 yards below the junction, and it was worked mostly by the local inhabitants.*

The Eastern Auriferous stream is formed by the junction of the Killahurler stream, with the stream, separating Mooreshill from Ballinvally and Knockmiller. The latter stream was proved by a branch of Weaver's Ballinvally trench: no gold has been recorded from it except a small nugget found by Mr. Acheson, near where it is crossed by the Arklow road. (This ford was formerly called Aughatinagat, which name is now disused.) In the eastward branch or Killahurler brook, Weaver made some trials and found some gold, but as the place was not promising he abandoned it.

From the confluence of these branches down to the Lyra (*anglice,* fork), a fair supply of gold has been obtained, while at Lyra a rich deposit was found—some of which was large gold. In the stream that comes in on the right bank at the Lyra, there are old workings for some distance up stream; and in the Monaglogh stream, coming in a little lower down on the same bank, large gold was also found. In the main stream, extensive workings have been carried on as far down as Rostygah, while in the stream separating this townland from Monaglogh, workings were prosecuted by Weaver, but only small sparks of gold obtained.

None of the dry ravines or "gulches" appear to have been explored in these valleys.

Résumé of Opinions on the probable Source of the Gold.

Notwithstanding all the trials and explorations which have been undertaken in the district, it has never been proved where the gold, and such of the associated minerals as tinstone and wolfram, occur *in situ;* because, as the alluvial deposits were followed up each stream, the gold in general became larger and more abundant, but suddenly ceased, or was only to be found in minute quantities, while the trenches opened above these places, also those cut at right angles to the streams above these rich deposits, failed to throw any light on the subject.

Mills, on account of the richness of the deposit at the ford of Ballinasilloge, was of opinion that north-west of this, some of the

* Griffith's gold locality, Killacloran, is probably on the lower waters of this stream, if not on the Clone stream to the North.

quartz veins would prove auriferous, on which account he proposed to drive a gigantic level—starting from below the "Gold Mine Lodge" (the house near the ford), and proceeding north-westerly to pierce the ridge of Ballinagore. This was never executed, but these veins seem all to have been cut, by the trench opened from the "Red hole," along the boundary between Ballinagore and Ballinasilloge, while Crockford's company are stated to have made open casts at right angles to the stream without being more successful.*

Weaver's suggestion was that these minerals occur disseminated widely, though in minute quantities, through the ro[illegible] of the mountain. He, however, acknowledged that the [illegible]n works did not support this opinion in any way, [illegible] negative evidence of where the gold was not to be fo[illegible]

Dr. Bartholomew Lloyd, in his first address as president [illegible] Dublin Geological Society, showed that as the rich deposit was so local the explorations might have been confined to the vicinity of that deposit.

Professor Warington W. Smith (in "The Records of the School of Mines": Vol. I., pt. iii., 1856) when writing of the lodes of Moneyteige and Ballycoog, states that he is "inclined to infer that it was the back or upper part of these lodes, the waste of which furnished the greater part of the alluvial metallic substances found in the valley below, and amongst them the gold." Weaver had made unsuccessful trials on these lodes, and the Carysfort company were not more fortunate in their trials on these and many others in the district, not even a trace of gold being found. So that unless the gold was rich in the upper portions, and altogether absent in the parts remaining, it is difficult to feel convinced that these are the sources, although it must be remembered that the pyrites at Ballymurtagh and Connary, further eastward on the same mineral channel, are slightly auriferous.

At a meeting of the Royal Geological Society of Ireland, in 1865, when a discussion took place on this district, it seems to have been generally supposed that the matrix of the gold would be found in the quartz reefs of the district.

* There is a deep cut through the village of Ballinasilloge down to the ford, but there is no record by whom executed—probably by Crockford.

Considerations on the Occurrence of the Gold.

Gold is known to occur in the gossan and also in the pyrites lodes at Ballymurtagh, though only in minute quantities, it also occurs in certain parts of the same mineral channel at Cronebane and Connary, but no "streamings" have ever been attempted in the gravels of the adjoining valleys and ravines. Traces of "black sand" have been observed in the gravels of the Ovoca below Newbridge; and as this valley cuts across the main mineral channel, it is not improbable that some sands, especially the deeper ones in it and its tributaries, may yet be proved to contain gold in fair proportions.

A continuation of this same mineral channel extends along the ridge overhanging the Gold Mine Valley, but no gold has been found in any of the lodes hereabouts.

That the auriferous vein or lode wherever it exists, has a quartz gangue, and contains many of the minerals found associated together in the valleys, appears to have been proved by the specimens collected by Weaver, who not only found gold and wolfram each attached to quartz, but also found them incorporated together and with ochre.*

The Carysfort company, in searching for this quartz lode, I am informed by Captain P. Argall, "about twenty-four years ago calcined and stamped three or four hundred tons of quartz at the Ballintemple mines, near Woodenbridge. This quartz was collected from all parts of the adjacent mountain, from loose blocks and from various outcrops of quartz veins intersected in the levels driven in search of lead and other ores, at the Moneyteige and Ballintemple mines. After calcination the quartz was stamped and amalgamated, and, as far as I can remember, *not a particle of gold was obtained.*"

From the spongy and porous condition of the gold, particularly the larger pieces, it may also be inferred that the lode probably contains much pyrites with which the gold was intimately blended, which having become decomposed is now only represented by the

* Fraser, in his Statistical Survey (1801), mentions these specimens attached to quartz, and accounts for their rarity by the fact that, as the peasants sold the gold by weight, all useless minerals were first detached. Also, Mr. J. Knight Boswell, stated (1865) that he had "a piece of quartz with gold all round it," but adds that it "was evidently the effect of water."

ochre found in the cavities of the nuggets. The specific gravity of the specimens varied from 12, that of the largest nugget, to 16, that of the fine grains, although the gold was 22 carats fine. The specific gravity of fine gold being 19·4, that of gold of the composition of that of Wicklow should be about 18.

While considering what is to be inferred from the distribution of the gold in the valleys, it is well to remember that the deposit in which it occurs is a recent one, and that the several water basins were necessarily, during the deposition of the gravels, very similar in extent and configuration to what they are at present; also, that at least towards the close of the period, the general features of the district were like what they are now, except perhaps a little more rugged and steep. The principal changes that have taken place since then, being a rounding and smoothing down of the hills and a filling up, especially the lower parts, of the valley.

From the nature of the gravel and the worn surfaces of the underlying rock, it is evident that a rapid current flowed down these valleys at some former period. Although the gold and associated minerals are now most abundant at the bottom of the gravel, it is not necessary that they should be deposited first—while the upper and poorer portions accumulated at a later time—because while the gravels were thoroughly flooded with water, the natural tendency of the finest and heaviest portions would have been to work their way downward towards the bed rock; and during heavy floods, the lighter portions on the surface would be carried forward, leaving the heavier higher up the stream.

The gravels in the lower lying portions of the adjoining valleys show that at one time these were estuaries; but as no sinkings have been made in the deep gravels of the auriferous streams, it is impossible to say whether they were estuarine or not when the deposition of the gold took place in the upper reaches.

The occurrence of the largest pieces of gold, with a greatest abundance of the associated mineral substances, particularly the tinstone, below certain points on each of the streams, above which they were either absent altogether or only traces of gold were to be found without the usually accompanying minerals, suggests each of these places being in the neighbourhood of the lode. Further-

more, as these places in the three principal streams are nearly in a straight line, the direction of which is at an angle of about 70° across the general direction of the beds, we might expect hereabouts the presence of a "caunter lode" that is not conformable to the strike of the strata,* or it may be that the auriferous veins are conformable to the main lodes (and to the strata), and are cut off by a fault on the line of the supposed caunter lode.

Most of the gold is apparently rolled as though it had been drifted. But some of the smaller grains or "eyesills," especially in the upper portions of the streams, are frosted or crystallized; and Weaver found some specimens "crystallized in octahedrons, and also in elongated garnet dodecahedrons," which would suggest either that the gold has not been carried far from its vein or lode, but was freed from its matrix near where it is now found, probably by the disintegration of an enclosing pyrites quartz. Or that it grew, or rather crystallized out, where it is now found.

If the latter supposition can be entertained it seems necessary that the gold should have been carried in solution and deposited in the drift. But to obtain a natural solution of gold presents many difficulties. In the first place the obtaining of a solvent, and secondly, the keeping of the gold in solution; especially if it be derived from a pyrites lode undergoing decomposition; the first stage in the oxidation of such being the formation of protosalts (especially of iron), in the presence of which it would be impossible that the gold could remain in solution; but if there were such a solution percolating the rocks, when it issued from under ground and mingled with waters containing easily oxidizable substances the gold, becoming reduced, would be precipitated. In a paper read before the Chemical Society in 1879, Mr. George Attwood, F.G.S., from his experiences in South America, states that nuggets do gradually increase in size owing to the accumulation of finely precipitated gold.† It has been advanced that

* Most of the exploration works carried out seem to have been projected on the supposition that the auriferous lode ran in the same direction as the principal lodes of the district, which is about N. 40° E. to N. 45° E.; there is another small system of lodes nearly at right angles to this, as Ballintemple, Clonwilliam, and some of the Moneyteige lodes.

† On the growth of gold, see Phillips, Proceedings Royal Society, Vol. XVI., page 294, and Skey, Chemical News, Vol. XXX., page 172.

the fact that the apparently exhausted gravels afford on rewashing a fresh supply of gold is a proof that it grows there. This, however, is more probably due to weathering and disintegration, as at Goldhill, North Carolina, where apyritous quartz is crushed to fine sand, amalgamated, and the gold extracted; this sand after lying for about a year is again amalgamated, and yields a crop nearly equal to the first, and this operation may sometimes be repeated four or five times.

In conclusion, we may consider what probabilities there are as to any quantity of gold remaining undisturbed in the county.

In the recognized auriferous valleys the peasants worked in the shallow deposits, and all subsequent explorers appear to have been unwilling to break new or deeper ground; while Weaver was directed only *to continue the workings till the covering became deep enough to prevent the peasants working it profitably.*

It appears that there are yet places in the county where trials might well be undertaken with a fair chance of success, such as:—

I. The shallow deposits or gravels (*shallow placers* of the Californian diggers), on the tributaries of the Ovoca river. It appears remarkable that Weaver did not seek after some of these in connection with his own mine (Cronebane), although portions of the lode were known to be auriferous. His trials round the summit of Croghan Kinshelagh, and his choice of the streams of Croghan Moira, seem to suggest that he had some peculiar idea as to the occurrence of the gold.*

II. The "bench diggings," *i.e.*, placers on the narrow benches on the slopes of the valleys above the present level of the rivers; these have not been looked for in any of the valleys of this district, nor are there many places where they could exist.

III. The deep gravels in the Ovoca river and its tributaries; the Daragh water and Gold Mine river:† these deep gravels have never been explored, although Fraser in his statistical survey (1801), recommended the estuarine flat above Arklow as a proper

* Captain P. Argall, who conducted the Cronebane mine for some time, informs me that "the Connary Mining Co. crushed and amalgamated a considerable quantity of quartz collected from the neighbourhood of their mines without obtaining any gold."

† Such accumulations could scarcely be analogous to the *deep placers* of California, which are in the ancient river system, above the present system of the country, often crossing it.

place for a trial. Higher up the rivers there are, however, places more favourably situated for such explorations.

IV. Quartz reefs in the Croghan Kinshelagh district, and other favourable localities. It has already been pointed out that no auriferous vein or lode has been found, the explorations only having narrowed the limits of its possible occurrence. If one lode or vein were proved auriferous, it would show to what system the auriferous lodes belong, and remove the difficulty of concluding whether they be auriferous continuously or only locally.

For more detailed information on the Wicklow Gold Mines, see Philosophical Transactions for 1796, and Royal Dublin Society's Transactions for 1800, 1801, 1802. Also Geological Society's Transactions, Vol. V., and Philosophical Magazine, 1835; Kane's Industrial Resources of Ireland, Calvert's Gold Rocks of Great Britain, Geological Society of Ireland, Vol. IV., page 269, and Vol. I. (N.S. 1865), page 97, Quarterly Journal of Science, Vol. XV., p. 189; also Mining Journal, Vol. X., p. 30 326; XI., p. 47, 213; XIX. p. 15; XXVI. p. 585, 653; XXXV. p. 472.

XXVI.—ALPHABETICAL LIST OF THE PARASITICAL ALGÆ OF THE FIRTH OF FORTH, BY GEORGE WILLIAM TRAILL, JOPPA, NEAR EDINBURGH.

Communicated by EDWARD PERCEVAL WRIGHT, M.D.

[Read April 17th, 1882.]

ON consulting the various works on British Marine Algæ, I have found that comparatively little attention has been specially directed to those species which are parasitical; and, in hopes of the subject proving of interest to the Royal Society of Dublin, I have prepared the following list of the parasites, along with their host plants, which I have observed on the shores of the Firth of Forth—a district sufficiently extensive and prolific to yield interesting results.

I have endeavoured to give, so far as possible, the periods of duration of the parasites and their host plants, with the times of fructification applicable to the former; and it will be seen that the parasite invariably attaches itself to a host plant of sufficient longevity to allow time for the development of its fruit and the escape of its spores, before the usual season arrives for the disappearance of the host plant; and, further, that the life-period of the parasite, irrespective of the time of fruit, is, in the great majority of cases, considerably shorter than that of its host plant.

The principle of natural selection in the parasite which is thus brought out, will, it is hoped, recommend the list to those who take an interest in this department of botany.

PARASITES alphabetically arranged, with periods of duration, times of fructification, &c.	HOST PLANTS in the order of frequency, with periods of duration.
Asperococcus echinatus. April to October. Sporangia in Summer. Sometimes on rocks.	Cladophora rupestris. All the year. Corallina officinalis. Perennial. Halidrys siliquosa, rarely. Perennial.
Bangia ciliaris. March to August. Fruit in Summer. ("Spring," *Le Jolis* and *Crouan.*)	Callithamnion mesocarpum. All the year. Sphacelaria radicans. Perennial. Chætopteris plumosa, rarely. Perennial. Rhodymenia palmetta, *var.* nicæensis, rarely. All the year.

PARASITES alphabetically arranged, with periods of duration, times of fructification, &c.	HOST PLANTS in the order of frequency, with periods of duration.
Callithamnion Hookeri. March to October. Fruit in Spring and Summer. Sometimes on rocks.	Cladostephus spongiosus. Perennial. Ptilota elegans. Do. Cladophora rupestris. All the year. Chondrus crispus. Perennial. Fucus vesiculosus. Do. Rhodomela lycopodioides. Do. Laurencia hybrida, rarely. All the year. "Fruit Winter and Spring." *Crouan.* "Keramidia, July," *Cresswell.* Polysiphonia nigrescens, rarely. Perennial. Delesseria alata, rarely. All the year.
Callithamnion polyspermum. February to October. Fruit, April to August. T. ("Spring," *Crouan.* "March—May," *Le Jolis.* "Summer," *S. O. Gray.*) Sometimes on rocks.	Polysiphonia fastigiata. Perennial. Cladophora rupestris. All the year. Ceramium rubrum, rarely. Do. " acanthonotum, rarely. All the year. Ceramium Deslongchampsii, rarely. All the year
Callithamnion roseum. March to October. Fruit, May to August. Sometimes on rocks.	Polysiphonia fastigiata. Perennial. Cladostephus spongiosus. Do. " distichus, rarely. Do. Polysiphonia nigrescens, " Do.
Callithamnion Borreri. All the year. Fruit April to August.	Chondrus crispus. Perennial. Ptilota elegans. Do. Cladostephus spongiosus. Do. Polysiphonia fastigiata. Do. Gigartina mamillosa, rarely. Do. Callitham. arbuscula, " Do. Polysiphonia nigrescens " Do.
Callithamnion Turneri. May to September. Fruit in Summer.	Polyides lumbricalis. Perennial. Furcellaria fastigiata. Do. Phyllophora Brodiæi. Do.
Callithamnion secundatum. *Ag.*: May to September. Fruit in Summer.	Rhodymenia palmata. Biennial. Porphyra laciniata. All the year. Sphacelaria radicans, rarely. Perennial.
Callithamnion sparsum. Summer, Autumn.	Laminaria digitata. Perennial.
Callithamnion arbuscula. Perennial. Fruit April to August. Usually on rocks.	Ptilota elegans, rarely. Perennial.

PARASITES alphabetically arranged, with periods of duration, times of fructification, &c.	HOST PLANTS in the order of frequency, with periods of duration.
Callithamnion floccosum. Spring annual. Fruit in April. Very rare in Firth of Forth.	Maugeria sanguinea. Biennial.
Callophyllis laciniata. All the year. Capsules in Spring. Granules in Summer.	Laminaria digitata. Perennial.
Calothrix confervicola. July to November. ("Summer," *Le Jolis.*)	Ceramium rubrum. All the year. ,, acanthonotum. Do. ,, Deslongchampsii. Do.
Ceramium rubrum. All the year. Fruit, July and August. Often on rocks. (Order of frequency of annexed host plants, approximate only.)	Chordaria flagelliformis. April to November, and later. Chorda lomentaria. March to November. Chondrus crispus. Perennial. Cladophora rupestris. All the year. Polysiphonia nigrescens. Perennial. ,, elongata. Do. Halidrys siliquosa. Do. Rhodomela subfusca. Do. Chætopteris plumosa. Do. Cladostephus spongiosus. Do. ,, distichus. Do. Polysiphonia atro-rubescens. All the year. Phyllitis cæspitosa. Mar. to Nov Some plants survive the winter. Chætomorpha melagonium. Perennia Chorda filum. April to December. Laminaria saccharina. Perennial. ,, digitata. Do. Saccharhiza bulbosa. Do. Rhodomela lycopodioides. Do. Rytiphlæa thuyoides. Do. Corallina officinalis. Do. Asperococcus echinatus. April to October. Dumontia filiformis. March to October. Many plants survive the winter. Cystoclonium purpurascens. April to October, *T.* (July to October, *Le Jolis*—Spring, summer. *Crouan.*) Laurencia hybrida. All the year. Ptilota elegans. Perennial. Fucus vesiculosus. Do. ,, serratus. Do. ,, platycarpus. Do. Griffithsia setacea. Do., rarely.

PARASITES alphabetically arranged, with periods of duration, times of fructification, &c.	HOST PLANTS in the order of frequency, with periods of duration.
Ceramium rubrum—*continued.*	Phyllophora membranifolia. Perennial, rarely. Cladophora lætevirens. March to December, or later. Gloiosiphonia capillaris. June to September, rarely.
Ceramium diaphanum. March to September. Fruit, July and August.	Halidrys siliquosa. Perennial. Polysiphonia nigrescens. Do. Cladostephus spongiosus. Do. Asperococcus echinatus. April to October. Chordaria flagelliformis. April to November, and later. Phyllitis fascia. March to November. Cladostephus distichus. Perennial. Fucus ceranoides, rarely. Do. Gloiosiphonia capillaris, rarely. June to September. Polysiphonia fibrillosa, rarely. Perennial.
Ceramium decurrens. June to September. Fruit, July and August.	Halidrys siliquosa. Perennial.
Ceramium Deslongchampsii. All the year. Fruit, August and September. T. ("May, June," *Le Jolis.*) Often on rocks.	Ptilota elegans. Perennial. Cladophora rupestris. All the year. Cladostephus spongiosus. Perennial. Chondrus crispus. Do. Corallina officinalis. Do. Polysiphonia nigrescens. Do. Laurencia hybrida, rarely. All the year. Cladostephus distichus, rarely. Perennial. Callithamnion Borreri, rarely. All the year. Halidrys siliquosa, rarely. Perennial.
Ceramium acanthonotum. All the year. T. (Fruit, "Winter and Spring," (*Le Jolis* and *Crouan.*) Usually on rocks.	Ptilota elegans. Perennial. Cladostephus distichus. Do. ,, spongiosus. Do. Chondrus crispus, rarely. Do. Gigartina mamillosa, rarely. Do.
Chordaria flagelliformis. April to November, and later. Fruit in Summer. Nearly always on rocks.	Corallina officinalis. Perennial.

PARASITES alphabetically arranged, with periods of duration, times of fructification, &c.	HOST PLANTS in the order of frequency, with periods of duration.
Chylocladia articulata. April to October. Fruit in Summer. Nearly always on rocks.	Laminaria digitata, rarely. Perennial. Fucus serratus, ,, Do. ,, vesiculosus, ,, Do.
Chylocladia clavellosa. April to October. Fruit in Summer. Nearly always on rocks.	Polyides lumbricalis, rarely. Perennial. Furcellaria fastigiata, ,, Perennial.
Cladophora lætevirens. March to December, or later. Usually on rocks.	Cladophora rupestris. All the year. Chondrus crispus. Perennial. Pol. nigrescens. Do. Ptilota elegans, rarely. Do. Lam. saccharina, ,, Do. Corallina officinalis, rarely. Do. Cladostephus spongiosus, rarely. Perennial.
Cladophora lanosa. April to August. T. ("Spring," *Crouan.*)	Polyides lumbricalis. Perennial. Ceramium rubrum. All the year. Halidrys siliquosa. Perennial. Furcellaria fastigiata. Do.
Cladophora rupestris. All the year. Usually on rocks.	Corallina officinalis. Perennial. Ptilota elegans, rarely. Do.
Chætomorpha melagonium. Perennial. Fruit in Summer. Usually on rocks.	Corallina officinalis. Perennial.
Chætomorpha tortuosa. May to October; but plants sometimes survive the winter.	Corallina officinalis. Perennial. Chondrus crispus. Do.
Corallina officinalis. Perennial. Fruit, Winter and Spring.	Himanthalia lorea (fronds). Perennial.
Chorda lomentaria. March to November. Trichosporangia. July and August. Usually on rocks.	Cladophora rupestris. All the year. Corallina officinalis, rarely. Perennial. Polysiphonia fibrillosa, rarely. Perennial.
Dasya coccinea. May to October. Fruit, July, August. Usually on rocks and acorn shells.	Laminaria digitata. Perennial.
Delesseria alata. All the year. Fruit in Spring. Often on rocks.	Lam. digitata. Perennial. Sacchariza bulbosa. Do. Rhodomela lycopodioides. Do. Ptilota elegans. Do. ,, plumosa. Do.

PARASITES alphabetically arranged, with periods of duration, times of fructification, &c.	HOST PLANTS in the order of frequency, with periods of duration.
Delesseria sinuosa. Biennial. Fruit in Winter. Often on rocks. Always submerged.	Lam. digitata. Perennial. Sacchariza bulbosa. Do. Odonthalia dentata. Do. Ptilota plumosa. Do.
Delesseria hypoglossum. "Summer annual." *Harvey.* Very rare in Firth of Forth.	Odonthalia dentata, rarely. Perennial.
Dermocarpa prasina. Found as yet only in January in the Firth of Forth.	Catenella opuntia. Perennial.
Dictyosiphon fœniculaceus, subspecies hispidus of Kjellman. April to August. Sporangia escape in July and August. T.	Chorda lomentaria. March to November. Chondrus crispus. Perennial. Phyllitis cæspitosa and debilis. March to November, and later. Fucus vesiculosus. Perennial. Halidrys siliquosa, rarely. Perennial. Gigartina mamillosa do.
Dictyosiphon fœniculaceus, subspecies flaccidus of Kjellman. April to August. Sporangia escape end of July. T.	Phlæospora tortilis. March to September. Chordaria flagelliformis, rarely. April to November, and later.
Dictyosiphon hippuroides. Aresch. Chordaria hippuroides. Agardh. May to September. Sporangia escape end of July and beginning of August. T.	Chordaria flagelliformis. April to November, and later.
Ectocarpus granulosus. April to October. Fruit, May to September. Usually on rocks. Always submerged.	Ceramium rubrum. All the year
Ectocarpus sphærophorus. April to September. Almost always in fruit.	Ptilota elegans. Perennial. Callitham. polyspermum. February to October. Cladophora rupestris. All the year. Callitham. arbuscula. Perennial. " Hookeri. March to October.

PARASITES alphabetically arranged, with periods of duration, times of fructification, &c.	HOST PLANTS in the order of frequency, with periods of duration.
Ectocarpus siliculosus. May to July. Fruit, June and July.	Corallina officinalis. Perennial. Cladophora rupestris. All the year. Chorda lomentaria. March to November. Chordaria flagelliformis. April to November, and later. Halidrys siliquosa. Perennial. Asperococcus echinatus. April to October. Chorda filum. April to December. Polysiphonia elongata. Perennial. Laminaria phyllitis. H. May to August. Pol. urceolata. March to October Some plants survive Winter. Rhodymenia palmata, rarely. Biennial. Ceram. Deslongchampsii, rarely. All the year. Myriotrichia clavæformis. May—Aug.
Ectocarpus brachiatus. Annual. Fruit, June and July. T. (" May, June." *Le Jolis.*)	Rhodymenia palmata. Biennial.
Ectocarpus fasciculatus. Annual. Summer and Autumn.	Laminaria saccharina. Perennial.
Ectocarpus secundus. Annual. May, September. Sometimes attached to shells.	Phyllitis cæspitosa. March to November, and later.
Ectocarpus littoralis. At all seasons. (Spring, Autumn. *Le Jolis.*) Often on muddy rocks.	Fucus serratus. Perennial. ,, vesiculosus. Do. Chorda lomentaria. March to November. Pol. fastigiata. Perennial. Halidrys siliquosa. Do. Cladophora rupestris. All the year. Callitham. arbuscula. Perennial. Lam. digitata. Do. Ulva latissima. "At all seasons." *Harvey.* Conferva melagonium. Perennial. Rhodymenia palmata. Biennial. Polysiphonia fibrillosa. Perennial.
Ectocarpus tomentosus. April to September. T. ("Summer." *Le Jolis* and *Crouan.*)	Fucus vesiculosus. Perennial. ,, serratus. Do. Himanthalia lorea. Do.

PARASITES alphabetically arranged, with periods of duration, times of fructification, &c.	HOST PLANTS in the order of frequency, with periods of duration.
Ectocarpus tessellatus. July to September. Fruit in August. T.	Laminaria saccharina. Perennial. Laminaria digitata. Do.
Elachista flaccida. June to September. Fruit, July and August.	Himanthalia lorea. Perennial. Halidrys siliquosa. Do. Fucus nodosus. Do. ,, vesiculosus. Do.
Elachista fucicola. June to September. Fruit, July and August.	Fucus serratus. Perennial. ,, vesiculosus. Do.
Elachista scutulata. Summer and Autumn.	Himanthalia lorea. Perennial.
Elachista (species?) June, July, August.	Halidrys siliquosa. Perennial. Ahnfeldtia plicata. Perennial. Laminaria saccharina. Perennial. } At Earlsferry in Fife. Rhodymenia palmata. Biennial.
Enteromorpha compressa. At all seasons. ("Autumn," *Crouan.*) Usually on rocks.	Corallina officinalis. Perennial. Cladophora rupestris. All the year. Chondrus crispus. Perennial. Halidrys siliquosa. Do. Ceramium rubrum. All the year. Lam. saccharina. Perennial. Cladophora lætevirens. March to December, and later. Chætopteris plumosa. Perennial. Chorda lomentaria. March to November. Cladostephus spongiosus. Perennial. ,, distichus. Do. Fucus ceranoides. Do. ,, vesiculosus. Do. Ahnfeldtia plicata. Do. Chordaria flagelliformis. April to November, and later. Polysiphonia fastigiata. Perennial. Callitham. arbuscula. Do. Rhodymenia palmata. Biennial. Dumontia filiformis. March to October. Many plants survive Winter. Polysiphonia nigrescens. Perennial.

PARASITES alphabetically arranged, with periods of duration, times of fructification, &c.	HOST PLANTS in the order of frequency, with periods of duration.
Fucus vesiculosus. Perennial. Fruit, January to Aug.	Cladostephus spongiosus. Perennial. ,, distichus, rarely. Do. Chætopteris plumosa, ,, Do. Chondrus crispus, ,, Do.
Laminaria saccharina. Perennial. Fruit, Summer and Autumn.	Chætopteris pulmosa, rarely. Perennial. Schizymenia edulis, very rarely at Island of Inchcolm. Perennial.
Leathesia tuberiformis. May to October. ("Summer." *Crouan* and *Le Jolis.*) Often on rocks.	Corallina officinalis. Perennial. Cladophora rupestris. All the year. Halidrys siliquosa. Perennial. Asperococcus echinatus. April to October. Laurencia hybrida. All the year. Pol. nigrescens. Perennial. ,, elongata, rarely. Do. Himanthalia lorea, rarely. Do. Cladophora lætevirens, rarely. March to December, or later.
Litosiphon laminariæ. June to October. Fruit in August.	Alaria esculenta. Perennial.
Litosiphon pusillus. Summer annual. Very rare in Frith of Forth.	Chorda filum. April to December.
* Melobesia pustulata. Perennial. ("Fruit in Autumn," *Crouan.*)	Chondrus crispus. Perennial. Gigartina mamillosa. Do. Himanthalia lorea. Do.
Mesogloia virescens. May to September. Fruit, August and September. Nearly always on rocks.	Laurencia hybrida. All the year
Myriotrichia filiformis and clavæformis. May—August. ("Spring," *Le Jolis* and *Crouan.*)	Asperococcus echinatus. April to October. Cladophora rupestris. All the year. Chorda lomentaria, rarely. March to November.
Myrionema strangulans April to August. ("Summer," *Crouan.*)	Enteromorpha compressa. At all seasons.

PARASITES alphabetically arranged, with periods of duration, times of fructification, &c.	HOST PLANTS in the order of frequency, with periods of duration.
Nitophyllum laceratum. May to September. Fruit in July.	Laminaria digitata. Perennial.
Nitophyllum punctatum. May to September. Fruit in Summer.	Desmarestia aculeata (old). Perennial.
*Maugeria Sanguinea. Biennial. Fruit in Winter.	Ptilota plumosa, rarely. Perennial.
*Plocamium coccineum. Perennial. Fruit, June and July. Usually on rocks in deep water.	Laminaria digitata. Perennial. Rhodomela lycopodioides. Do. Polyides lumbricalis. Do. Odonthalia dentata, rarely. Do.
Polysiphonia urceolata. March to October. Some plants survive Winter. ("Fruit, Spring," *Le Jolis* and *Crouan*). Nearly always on rocks.	Cladophora uncialis, rarely. From Spring one year until Summer the next—at Dunbar, &c. Laminaria digitata. Perennial.
Polysiphonia fibrillosa. Perennial. Fruit, July to September. Nearly always on rocks.	Cladostephus spongiosus. Perennial.
Polysiphonia fibrata. Summer and Autumn. Fruit, August. Nearly always on rocks.	Corallina officinalis. Perennial.
Polysiphonia nigrescens. Perennial. Fruit in Summer. Nearly always on rocks.	Corallina officinalis. Perennial.
Polysiphonia fastigiata. Perennial. Fruit, June to September. Occurs on rocks at Broxmouth.	Fucus nodosus. Perennial.
Polysiphonia parasitica. June to September. Tetraspores, July and August. Usually on rocks near low water.	Ptilota plumosa, very rarely. Perennial.
*Phyllitis cæspitosa. March to November. Some plants survive the Winter. Trichosporangia in Spring and Summer.	Fucus vesiculosus, very rarely. Perennial.

PARASITES alphabetically arranged, with periods of duration, times of fructification, &c.	HOST PLANTS in the order of frequency, with periods of duration.
Polysiphonia atro-rubescens. All the year. ("Fruit, Winter," *Le Jolis.*) ("Winter and Spring," *Crouan*). Usually on rocks at limit of low tides.	Polysiphonia elongata, rarely. Perennial.
Porphyra laciniata. All the year. Usually on rocks	Corallina officinalis. Perennial. Callitham. arbuscula. Do. Himanthalia lorea. Do. Polysiphonia fibrillosa. Do. Cladophora rupestris, rarely. All the year.
Ptilota plumosa. Perennial. Fruit, July and August.	Laminaria digitata. Perennial. Rhodomela lycopodioides, rarely. Perennial. Polyides lumbricalis, very rarely at Dunbar. Perennial.
Rhodymenia palmata Biennial. Cystocarps, July and August. T. ("Spring," *Crouan.* "Fruit, November to February," *Le Jolis.*) Tetraspores, February.	Ahnfeldtia plicata, rarely. Perennial. Lam. digitata, ,, Do. Fucus serratus, ,, Do. ,, vesiculosus, ,, Do.
Rhodomela lycopodioides. Perennial. Fruit, March to June. T.	Laminaria digitata. Perennial.
Rhizoclonium riparium. January to August. T. ("Winter and Spring," *Crouan.* "All the year," *Le Jolis.*)	Fucus vesiculosus. Perennial.
Rivularia atra. All the year? Often on rocks. Always submerged.	Corallina officinalis. Perennial. Cladophora rupestris. All the year. Cladostephus spongiosus. Perennial.
Sphacelaria cirrhosa. All the year. Fruit, June and July.	Halidrys siliquosa. Perennial. Cladostephus distichus. Do. Polysiphonia fibrillosa. Do., rarely.
Ulothrix flacca. Annual. November to August. T. Fruit in Winter and Spring. Usually on rocks near high water.	Fucus vesiculosus. Perennial. Callithamnion Rothii. Do. Corallina officinalis. Do. Fucus platycarpus. Do.

PARASITES alphabetically arranged, with periods of duration, times of fructification, &c.	HOST PLANTS in the order of frequency, with periods of duration.
Urospora pencilliformis. Annual. November to August. T. Fruit in Winter and Spring. Usually on rocks near high water.	Fucus vesiculosus. Perennial. Callithamnion Rothii. Do. Fucus platycarpus. Do.
Ulva latissima. "At all seasons," *Harvey*. Usually on rocks.	Cladophora lætevirens. March to December, or later. Cladophora rupestris. All the year. Corallina officinalis. Perennial. Ceramium rubrum. All the year. Cladostephus spongiosus. Perennial. Ptilota elegans. Do. Chordaria flagelliformis. April to November, and later. Cystoclonium purpurascens. April to October. Chætopteris plumosa. Perennial. Cladostephus distichus. Do. Rhodymenia palmata. Biennial. Fucus serratus. Perennial. ,, vesiculosus. Do. Chondrus crispus. Do.
Ulva lactuca. March to June. T. ("Spring," *Crouan*. "February to April," *Le Jolis*.)	Cladophora rupestris. All the year.

Notes added in the Press.

Laurencia hybrida. All the year. Fruit, granular, in Winter and Spring; Keramidia in July. Usually on rocks.	Fucus serratus. Perennial. Rarely.
Laurencia pinnatifida. All the year. Fruit, granular, in Winter and Spring; Keramida in July. Usually on rocks.	Rhodomela lycopodioides. Perennial. Rarely.
Ceramium strictum. Annual, Spring and Summer. Usually on rocks.	Cladostephus spongiosus. Perennial.

XXVII.—CATALOGUE OF THE EXAMPLES OF METEORIC FALLS IN THE MUSEUMS OF DUBLIN, BY PROF. V. BALL, M.A., F.R.S.

[Read May 15th, 1882.]

THE present paper is the first of a series which I hope to publish from time to time, giving an account of various collections which are preserved in the Geological Museum of Trinity College. Where possible, and when the necessary permission is obtained, I intend to include information regarding collections in other Museums besides that which is under my own charge. The publication of such lists has for its object the conveyance to those likely to be interested, information regarding the existence in our Museums of authentic examples of the specimens indicated, and I am not without hope that it may lead to our series being made more perfect by donations and exchanges. Possessors of single examples and small collections, may be induced to contribute them to Museums if they receive the assurance that they will be well cared for.

Far removed in size and importance as the collection here described is from those which are preserved in the British Museum, in the Imperial Museum, Vienna, and in the Indian Museum, Calcutta, it serves sufficiently well to illustrate the leading forms and lithological characters possessed by these interesting objects—objects which are now, perhaps, more than at any previous time, exciting interest and attention, owing to the fact having been recognised that they afford, as it were, hand specimens of what our earth was when it first consolidated, and before organic life made its appearance.

Ireland has contributed only four examples; these all belong to the class of aerolites, and the circumstances attending their falls, respectively, are on record. A fifth fall was reported to have taken place at Cloneen, near Parsonstown, King's county, in August, 1828. A sample preserved in the National Museum is accompanied by a statement that "the fall caused the death of two men, injury to a woman, and the ignition of a stack of oats." No one having any knowledge of the appearance presented by meteorites could possibly regard this sample as being other than spurious. It is in fact, in all probability, a fragment of slag from some smelting furnace. The injury described was probably caused by a flash of lightning.

The four authentic falls are—

1. Mooresfort, Co. Tipperary, . .	August, 1810.
2. Adare, Co. Limerick, . . .	September 10, 1813.
3. Killeter, Co. Tyrone, . . .	April 29, 1844.
4. Dundrum, Co. Tipperary, . .	August 12, 1865.

The Killeter fall is described as "a shower of aerolites," but no specimens are preserved in our local Museums, and there is only a small one weighing 2·7 grammes in the British Museum, and another of about the same weight in the Calcutta Museum.

It may be convenient to quote here for easy reference the published analyses of these falls.

MOORESFORT, *Prof. Higgins,* Proceedings, Royal Dublin Society, Vol. XLVII., 1811.

Silica, ...	48·25
Iron, ...	39·
Magnesia, ...	9·
Sulphur, ...	4·
Nickel, ...	1·75
	102·

ADARE, *Dr. Apjohn,* Transactions, Royal Irish Academy, Vol. XVIII., 1839, p. 17.

Iron and Nickel, . . .	23·07
Magnetic Pyrites, . . .	4·38
Chrome Iron, ...	3·34
Earthy Matrix, ...	68·47
Alkalies and loss, . . .	0·74
	100·

KILLETER, *Rev. Dr. Haughton,* Proceedings, Royal Irish Academy, Vol. IX., 1867, p. 341.

Hornblendic Mineral (insoluble in acid), . .	34·18
Earthy Mineral (soluble in acid), . . .	30·42
Iron, ...	25·14
Nickel, ...	1·42
Sesquioxide of Chrome, ...	2·70
Cobalt, ...	trace
Magnetic Pyrites, ...	6·14
	100·00

DUNDRUM, *Rev. Dr. Haughton,* Proceedings, Royal Irish Academy, Vol. IX., 1867, p. 336.

Nickel Iron, ...	20·60	{ Iron, 19·57 Nickel, 1·03
Sulphur Iron, ...	4·05	
Chrome Iron, ...	1·50	
Chrysolite	33·08	
Earthy Minerals, insol. in HCl., .	40·77	
	100·	

The weights are given in grammes, as in the British Museum Catalogue.—1 gramme = 15,432 grains.

—	Date of Fall or Find.	Weight in Grammes.
I. AEROLITES (ASIDERITES AND SPORADOSIDERITES.)		
1. BENARES, India. Probably a portion of the so-called Krakhut fall of December 19, 1798. Fractured surface partly glazed, ...	—	115·9
2. L'AIGLE, Orne, France, ...	April 26, 1803, . .	15·9
2*a*. Do. Sample in Museum of Science and Art, Dublin, ...	Do., . .	218
3. WESTON, Connecticut, U.S.A., ...	December 14, 1807, .	6·4
3*a*. Do. do. Sample in Museum of Science and Art, Dublin, ...	Do., . .	51·7
4. STANNERN, Iglau, Moravia, ...	May 22, 1808, . . .	11·7
4*a*. Do. do. Two samples in Museum of Science and Art, Dublin, ...	—	265·
5. MOORESFORT, Co. Tipperary. Sample in Museum of Science and Art, Dublin. Also a cast of original stone, ...	August, 1800, . . .	1255·5
6. CHARSONVILLE, near Orleans, France, . . .	November 23, 1810, .	14·8
7. BERLANGUILLAS, near Burgos, Spain, . . .	July 8, 1811, . . .	21·6
7*a*. Do. do. Sample in Museum of Science and Art, Dublin, . .	—	13·8
8. CHANTONNAY, Vendée, France. Sample in Museum of Science and Art, Dublin, ...	August 5, 1812, . .	11·
9. LIMERICK (Adare, Faha, &c.), ...	September 10, 1813, .	155·
9*a*. Do., ...	Do., . .	67·1
9*b*. Do. Sample in Museum of Science and Art, Dublin, ...	Do., . .	134·9
10. DURALA, Patiala, India. Cast in Museum of Science and Art, Dublin, ...	February 18, 1815, .	—
11. CHASSIGNY, near Langres, France, ...	October 3, 1815, . .	8·7
11*a*. Do., do., Sample in Museum of Science and Art, Dublin, ...	Do., .	16·3
12. NANJEMOY, Maryland, U.S.A., ...	February 10, 1825, . .	38·9

—	Date of Fall or Find.	Weight in Grammes.
13. FORSYTH, Georgia, U.S.A.,	May 8, 1829,	6·5
14. CHANDAKAPUR, Berar, India,	June 6, 1838,	2·7
15. COLD BOKKEVELDT, Cape of Good Hope,	October 13, 1838,	2·7
16. CHATEAU REYNARD, Loiret, France,	June 12, 1841,	8·2
16*a*. Do. do. Sample in Museum of Science and Art, Dublin,	Do.,	16·6
17. BISHOPVILLE, S. Carolina, U.S.A.,	March 25, 1843,	1·9
17*b*. Do. do. Another sample? fragments and dust,	—	7·9
18. NEW CONCORD, Muskingum Co., Ohio, U.S.A.,	May 1, 1860,	4·8
19. DHURMSALA, Punjab, India,	July 14, 1860,	216·3
20. BATSURA, &c., Champaran, India. Casts of separate fragments,	May 12, 1861,	—
21. DUNDRUM, Tipperary,	August 12, 1865,	2158·7
21*a*. Cast of ditto in Museum of Science and Art, Dublin,	—	—
22. MASSACHUSETS. History of this fall not known,	—	4·8
II. SIDEROLITES (SYSSIDERITES.)		
23. KRASNOJARSK, Siberia. Known as the Pallas Iron,	Found, 1772,	4·4
23*a*. Do., do., do.,	—	9·6
23*b*. Several samples in Museum of Science and Art, Dublin,	—	—
24. BREITENBACH, Bohemia. Cast,	„ 1861,	—
25. ESTHERVILLE, Emmet Co., Iowa, U.S.A.,	Fell, May 10, 1879,	1·9
III. SIDERITES (AEROSIDERITES.)		
26. SCRIBA, Oswego Co., New York, U.S.A.,	Found, 1814,	16·1
27. LOCKPORT, New York, U.S.A.,	„ 1818,	5·4
28. BURLINGTON, Otsego Co., New York,	„ 1819,	16·1
29. WALKER (or MORGAN ?) Co., Alabama, U.S.A.,	, 1832,	10·4
30. ROWTON, near Wellington, Shropshire. Cast,	Fell April 20, 1876,	—
31.* TENNESSEE, U.S.A.,	—	24·1
32.* Do., do.,	—	11·4

NOTE.—There is a small sample of the Ovifak (terrestrial) iron in the Museum of Science and Art, Dublin.

* The labels on Nos. 31 and 32 do not show to whic of the known Tennessee finds the examples belong.

SCIENTIFIC PUBLICATIONS OF THE ROYAL DUBLIN SOCIETY.

TRANSACTIONS: *Quarto, in parts, stitched.*

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Part 2.—Pages 33 to 60. (April, 1881.)
Part 3.—Pages 61 to 150. (July, 1881.)
Part 4.—Pages 151 to 168. (October, 1881.)
Part 5.—Pages 169 to 301. (August, 1882.)

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CONTENTS.

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27. Lockport, New York, U.S A.,	„ 1818,	5·4
28. Burlington, Otsego Co., New York,	„ 1819,	16·1
29. Walker (or Morgan ?) Co., Alabama, U.S.A.,	„ 1832,	10·4
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31.* Tennessee, U.S.A.,	—	24·1
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XXVIII.—NOTES ON THE RECOVERY OF COPPER FROM ITS SOLUTION IN MINE DRAINAGE WITH SPECIAL REFERENCE TO THE WICKLOW MINES. By PHILIP ARGALL AND GERRARD A. KINAHAN. Plates XXII and XXIII.

[Read, June 19th, 1882.]

Introduction.

In these notes it was originally intended simply to describe some of the more interesting points in connexion with cementation, or the precipitation of copper, as practised at the Copper Mines of Cronebane, Co. Wicklow; but on considering the matter further it appeared that more general interest might be attached to them if the subject were treated somewhat differently, and some notice given of the methods of precipitation and general working adopted at other mines and metallurgical works.

The following pages are therefore devoted to the Ovoca Mines, with a condensed summary of the principal points in some of the processes adopted at other places, references are given in most cases to those works where more detailed information in each case may be obtained.

Cementation of Mine Waters.

The phenomenon of cementation, or the precipitation of copper from solution in water on metallic iron, appears to have been noticed at a very early period, for Agricola, who wrote in 1546, mentions it in connexion with the waters of Schmöllnitz.

When and where it was first turned to practical account it is difficult to determine, but the ordinary process seems to have been in operation in Spain (Rio Tinto) since 1661, and Dr. Edward Brown, in the Philosophical Transactions for 1670, describes the process as practised at the Ziment Springs, Herrengrund. At Agordo in the Venetian Alps, it was introduced in 1692, from Germany, by Frederic Wegberg, a Prussian engineer.

It is recorded that the phenomenon was noticed in 1728, at the Chacewater mine, near Redruth, Cornwall, but it was not turned to practical account there till 1854. The first practical application of it in the British Islands, seems to have been at the Cronebane

mines, Co. Wicklow, where Dr. Henry Kenroy, when describing the waters in 1751, states that the process was discovered there by a shovel which had been left for some time in the mine water being turned into copper. Mr. Matthew Johnston, one of the proprietors of the mine, then proposed recovering the copper from the mine water by this method.*

The plan adopted by him was the following, which is interesting, as being the first method used in this country.†

The drainage of the mines was run into a chain of oblong pits, each ten feet long, four wide, and eight deep, the bottoms of which were laid with smooth flags and the sides built up with stones and lime with rude wooden beams across the pits to lay the iron bars on. The copper replaced the iron, which passed off in solution; to hasten this reaction, the iron bars were frequently taken up and the copper rubbed off into the pit; in about twelve months the whole bar was dissolved if the iron was soft; but hard iron or steel were acted on less quickly and therefore were not found to answer so well. When the iron was all dissolved the water was turned off the pit, and the copper shovelled out; this red copper mud was laid in heaps and when dry became a reddish dust. One ton of iron produced one ton nineteen and a-half cwt. of this copper, and each ton of which produced sixteen cwt. of pure copper; that is to say, one ton of iron was sufficient to produce one ton eleven and a-half cwt. of copper, which was worth £10 more per ton than the copper smelted from the ore.

It was subsequently found advantageous to run the drainage into settling pits, and to pass only the clear waters over the irons. Evidently only a small quantity of the copper in solution was saved, as it appeared that the pits might be continued as far as the workers pleased; for the waters did not sensibly abate in quality by being subjected to the process. The quantity of copper running waste about this time must have been enormous, as in

* Price (Mineralogia Cornubiensis (1778) p. 291), gives the credit of its adoption here to some Cornish miners who, having emigrated from Chacewater, settled at Cronebane, and adds, "Captain Thomas Butler, who was one of Redruth, and manager of that mine (Cronebane), persuaded the proprietors to adopt the scheme of precipitating copper."

† The following account is compiled from Dr. Kenroy's paper in the Philosophical Transactions for 1751. There appears to be some inaccuracy in the statement of the quantity of precipitated copper produced. Compare page 317, and No. XXVI., Table A.

one stream, "The Sulphur Brook," it was calculated to be 129,600 grains per minute, or 124,100 lbs. per annum. Subsequently the poor pyrites of the district was calcined and added to the waters in order to enrich it in copper salts.

During Weaver's management of the mines the method of procedure was practically that just described, but since then it has been considerably modified. The precipitating pits have been replaced by launders, through which the waters are conducted over irons which are strewn along the bottom. These launders are sometimes highly inclined, but of late years the tendency appears to have been to reduce the angle of inclination as much as possible, so that now, in many cases, the slope is only sufficient to allow of a steady and continuous flow of the waters.

General Method of Procedure adopted at the Ovoca Mines.

The water, as it issues from the mine adit or pumphead, is conducted into a settling pond to allow of the deposition of suspended material (ochre, grit, &c.) from which the waters pass to the precipitating launders, which are usually twelve to eighteen inches wide and nine inches deep, set at various inclinations, according to the judgment of those in charge, or as determined by the surface of the ground; the slopes vary from one in six to one in twelve; an average would be probably about one in ten. The precipitation works are situated, whenever possible, on the side of a hill or on rapidly falling ground, as this admits of great variation in the slope of the launders. The bottom of the launders is covered for a depth of about three inches, with broken pieces of cast and bar iron, over which the waters (having been freed from suspended material) are caused to pass. Small settling pits (hutches), usually made of wood, and varying in capacity from 900 to 1,500 gallons, are fixed at intervals of about 200 yards, and every twelve hours the water is run off from these hutches, and the metals in the launders are brushed over, raked, and again brushed, when the greater part of the precipitate copper which had accumulated on them during the previous twelve hours is carried off in suspension, and run into the hutches, where it is allowed to settle for the next twelve hours, when, preparatory to again brushing the irons in the launders, the water is run off the hutches to within about four inches of the precipitate at the bottom. (See Figs. 1 and 2, Plate XXII.)

The settling pits or hutches and the launders, where the inclination is slight, are cleared out about once a quarter, and the copper precipitate so obtained is passed through a perforated copper sieve, of about eight or ten holes per linear inch, the small pieces of iron and scales of copper are retained on the sieve, the latter being carefully picked out and added to the sifted precipitate. This, when it has properly settled in the *sifting hutch* becomes a stiff mass, which is extracted and taken to the drying kiln, when slabs of fire-clay or cast-iron are placed across flues and heated from underneath, when the water is driven off and the most of the copper converted to oxide, the greater the heat the more effectually the latter is accomplished. At some mines the precipitate is sundried, and in others it is packed in the raw state, containing five or six per cent. of water, which keeps the copper bright and fresh, and allows of its being barrelled with little loss or injury. In either case, after packing in barrels, the precipitate is despatched to Swansea.

Remarks on this Method of Procedure.

In practice the foregoing general method of procedure has several serious objections, some of these it may be well to point out as concisely as possible.

As regards the disposition of the launders it has been found that, with moderately rich copper solutions, very little inclination is required; in fact, that the less agitated the waters are, under these circumstances, provided a steady continuous flow is maintained, the richer will be the resultant precipitate, which, at the same time, will be more abundant for a given quantity of iron consumed. When agitation takes place, not only is the consumption of iron excessive, but owing to aeration of the water, oxidation of the iron salts takes place and ochre is deposited, which, covering the metals, prevents the further action of the copper solution upon them.

Regarding the cleansing of the metals, in some mines they are brushed twice in twelve hours, being violently agitated with rakes and vigorously scrubbed with the brooms; as a consequence, the softer parts of the iron and graphite are carried away with the copper to the settling hutch, when, not only do they largely contaminate the precipitate but are also rendered useless for precipitating a further quantity of copper, as, being buried in

the precipitate they are protected from contact with the copper solution. It will be found, that where this system is practised, not only is the proportion of iron required to produce a ton of fine copper very high, but the precipitate is always of low quality and mixed with phosphorus and deleterious ingredients.

Thirdly, concerning the sifting and drying: Numerous small scales and grains of copper find their way to the waste heap along with the small pieces of iron sifted out in this process, in fact this refuse consists principally of cast-iron, oxide of iron graphite, and copper to the extent of from 4 to 12 per cent.; this, however, might be recovered if the broken pieces of cast-iron were carefully freed from rust and returned to the precipitating shoots to be thoroughly dissolved.

When the precipitate is heated not only is the water driven off but the copper is oxidized to a greater or less extent, so that it is a question whether there is anything gained by this process of drying, for, in the first place, the precipitate loses 5 to 10 per cent., while the amount lost in dust, &c., during the drying and packing is often considerable, and attended with very injurious consequences to the health of the workmen.

Methods of Precipitation adopted under Special Circumstances.

In some of the mines of this district, particularly in those of Cronebane, precipitation of the copper underground has been successfully carried out, and, although the liquors cannot be so thoroughly exhausted as at surface, yet there are many advantages to commend the adoption of this method—Firstly, the waters are taken fresh from the "stulls" and workings, and the copper is extracted before the liquors are contaminated by extraneous matter, or before ferric sulphate or basic salts are formed; secondly, the water being of a higher temperature (sometimes up to 70° F.), precipitation is more rapid and efficient, with a richer precipitate.

In the Cronebane mines, peculiar tanks were adopted (See Figs. 3 and 4, Plate XXII.), with great advantage in economizing space, these tanks were two feet deep and eighteen inches wide, and of lengths varying according to the space to be occupied; at every four feet, divisions (*f*) were placed that extended from the bottom to within six or eight inches of the top, between each two of these divisions a

wooden grating (rr') was supported at about six inches from the bottom of the tank; on the top of this grating and about midway between the fixed partitions (f), a movable partition (m), sliding in a groove, was run down from the top, to which it extended. The gratings were covered with metals to the depth of about one foot. By this disposition of the grating and the partition, the course of the water is as follows:—Coming in over one of the fixed partitions it spreads out over the metals, passes through them and the grating into the open space below, then flowing under the movable partition, it rises through the grating and metals on the opposite side and flows over the fixed partition into the next division in it to take a similar course. In this way, the water is brought into intimate contact with a large body of metals with very little agitation, and the precipitate on becoming detached, accumulates in the space below the grating. These tanks were filled up with broken pieces of pig-iron, which were shaken up and turned over about twice a week, when the precipitate subsides under the grating, from which it is taken once a quarter.

This form of launder was found specially serviceable in short and wide spaces underground, where several lengths of them could be placed side by side, and the waters passed backwards and forward through them.*

In narrow levels, other forms of launders were used; thus, in the old headings and exploration drifts, the waters were caught at the entrance as high as possible and carried forward in launders (I) supported at the side of the level, and having a fall of about one in fifty. (See Plate XXIII., Fig. 1.) When they reached the far end, the waters were discharged into the return launders (E), which were placed on the other side of the level but much nearer the floor. As almost the whole of the lower part of the level was thus occupied, an overhead tramway (R) was placed above for the conveyance of the metals to the launders and for the removal of the precipitate. For this, a single wire rope was stretched along the level, at about nine inches from the roof, one end being firmly fastened, the other having an arrangement for tightening up by means of a screw. This rope was supported along the level by iron supports (S), hollowed

* Thus, in one space twelve feet square, the waters passed through more than fifteen tons of pig-iron.

out at the top to fit the rope (see Plate XXIII., Figs. 3 and 4), these were driven either into the roof or into one wall of the drift, and were placed at intervals of eight or ten feet where the run was straight, but on curves were more numerous. To run on this, two small grooved wheels were connected together from centre to centre by a small iron plate, a strap embraced each wheel and was terminated at the lower end by a hook, from which a box about two feet long by fourteen inches wide and fourteen inches deep, was suspended (Fig. 2, Plate XXIII.), this could contain about three cwt. of cast-iron or of precipitate, and could be easily propelled by a boy. This arrangement was found to answer admirably, and only under the most exceptional circumstances left the track.

In the adit and main levels the launders were laid on sleepers stretched from wall to wall near the bottom, but leaving a space underneath for overflow or excessive floods (Fig. 5, Plate XXIII.) The sides of the launders sloped outward, and were supported laterally by the blocks of wood on which the tramway rails were laid; a small waggon on these rails was thus placed over the launders, and from it the metals were distributed to the launders, or the precipitate cleaned up into it; by fixing a revolving brush to one of these waggons a rapid means of sweeping the metals was secured.

The method just described, is well adapted for treating the water underground, where the drifts are tolerably level and the water of average richness, but, as previously stated, there is some difficulty in extracting the last portions of the copper when the waters deposit ochre. Precipitation of copper underground is then at an end, unless there is some rapidly falling drift to run the water through, for, it is remarkable, that this semi-spent water, if kept in a state of rest or slow motion, will deposit ochre on the metals in the launder and protect them from further action of the waters;* but, if allowed to fall for a short distance on the metals copper will be again precipitated, or if the inclination of the launder is increased so that the water passes briskly over the metals, the same result will be obtained, more especially if wrought-iron is substituted for cast, and the greater the velocity of the water, provided it is not strong enough to wash away the copper, the better will be the result. At surface, then, if this apparently spent water be run down a steeply inclined launder containing angular stones and fragments of iron, so as to become thoroughly agitated,

* Compare page 316.

much of the iron in solution separates, as ochre,* and may be removed by allowing it to deposit in large settling ponds. On passing the clear water from these ponds through another series of highly inclined precipitating launders, clean copper will be deposited. By proceeding in this manner, not only may the waters be exhausted of the contained copper, but large quantities of ochre extracted and saved.

It has been often observed that the longer the precipitated copper is allowed to remain on the iron, the purer it becomes, and it is only a question of time to convert the loose granular precipitate into a sheet of malleable copper, that protects the iron to a great extent; before this is accomplished a dense crystalline deposit of copper, of great purity, is produced. The most favourable time for detaching the precipitate appears to be when this stage in the process has been reached—this is usually from thirty-five to fifty-five hours in tolerably strong water, after the metals have been put in. It seems, therefore, that about once in forty-eight hours would be sufficiently often for cleaning the metals, as then the precipitate would be in a granular crystalline state, not coherent enough to resist disintegration.

Sudden floods, and specially those after *warm weather* are usually very rich in copper salts, and there is often considerable difficulty in dealing with them so as to save all the copper. For this purpose tin clippings, specially those having the coating of tin removed, are admirably adapted; they are let into the launders as the floods come down which, if rich, dissolve them in a very short time. Spare launders might also be provided and kept stocked, either with clippings or ordinary metals; so that during floods the waters could be turned on to them.

Precipitation in other Districts.

Copper is now extracted from the drainage of almost all active copper mines; in many mining districts the poor copper ores are treated at the mine by some wet process, as it has been found that ores containing but $1\frac{1}{4}$ per cent. of copper, will pay when treated thus. However, in this country, these processes seem to have been greatly neglected, and when the mine drainage has been treated, the results as a rule have been poor (as may be seen from the annexed table), as the attempts to improve these

* This is probably due to the reaction noted by Wagner which is mentioned on page 320.

results are few, although at other metallurgical works important modifications have been introduced with very satisfactory results, some of which will be noticed presently.

At Pary's Mine, Anglesea, both a rude wet process for treating the poor ores, and a treatment of the mine drainage were practised over a century ago. The former seems to have been abandoned, but the latter has been continued with little alteration.* The waters are run through a series of large tanks containing scrap-iron; in each tank the waters remain in contact with the metals for some time before being drawn off to the next lowest in the series; in this manner the waters are passed from one tank to another, and are altogether about ten weeks under treatment. At Mona Mine a similar method of procedure seems to have been adopted.

The mine waters of the Devonshire Great Consolidated Copper Mines, and of Wheal Agar, near Crow's Nest, Cornwall, have also been treated for the contained copper. Since 1804 pits have been opened along the Great Gwennap adit, Cornwall, but the results have been very low. (Table A, No. VI.) At Huel Margery, St. Ives, the copper solutions have been heated by a steam jet which has been found greatly to accelerate precipitation. Copper is also extracted from the washings after calcination of the tin ores containing pyrites.†

On the Continent of Europe we find that copper is often extracted from its solutions. The following are some examples:—

At Rio Tinto (Huelva) both the mine drainage and the poor ores are treated. The one is known as "*natural cementation*," the other as "*artificial cementation*." The ordinary method of precipitation on iron seems to have been known for over 200 years. In the San Roque adit the launders are over 1000 yards long, and contain pig-iron, which in ten days is coated with a hard metallic coating of copper containing 80 per cent. of pure metal. These scales are removed to expose a fresh surface of iron, and are said to be so hard as to resist a file, and ring when struck with a hammer. The mine drainage of Tharsis (Huelva) and San Domingos (Portugal) are similarly treated.‡

* See T. F. Evans in Trans. Manchester Geological Society, Vol. XIV., p. 367.

† Cementation appears to have been discontinued in Cornwall of late, as Anglesea and Leinster, Ireland, are the only localities whose returns of copper precipitate appear in the Mining Inspector's Report for 1881.

‡ In "artificial cementation" as conducted at Rio Tinto, the ore is calcined in bee-hive shaped heaps or "*teleras*," containing from 100 to 500 tons. When lighted a slow combustion continues for eight or nine months, when burnt out the ore is "removed to large

At Herrengrund (Hungary) the waters are run through inclined troughs, the bottoms of which are stepped and covered with irons.

At Schmöllnitz the waters are conducted through precipitating vessels twelve feet long, twelve inches broad, and ten inches deep connected with each other, and arranged in terraces, in which the pieces of cast-iron are piled in lattice fashion; when most of the copper has been precipitated the solution becomes muddy and deposits basic salts. It is then conducted by a gutter into vertical vessels furnished with iron plates, and the precipitation of the remaining copper is thus facilitated by the impact of the solution upon the precipitating iron. The iron plates are cleaned daily, and the cement copper is removed every fortnight from the first vessels, and every four weeks from the lowest. Of other localities where mine drainage is treated, may be mentioned Falun (Sweden), Rammelsberg (Hartz), and Agordo (Venetian Alps). The method for treating poor ores at the latter place will be noticed further on. (Page 320).

tanks; each some sixty feet long, sixteen feet in width, and three feet in depth, where it is lixiviated by successive additions of water, which, after dissolving out the salts of copper, is run through an extensive labyrinth of tanks, in which pig-iron is regularly stacked in hollow piles." Here the iron is dissolved, and "the copper in a metallic granular state, but contaminated with the carbon and other impurities of the pig-iron, is deposited. In order to collect this precipitated copper the liquors are diverted in succession from the various tanks, forming portions of the arrangement for precipitation, the liquids drawn off and the iron removed from one end of the tank, and adhering copper being brushed off. The copper in the bottom of the tank is now collected, and the cleaned iron replaced with an addition of fresh pig, the operation being continued with the next stack in succession, until the whole of the pig-iron has been cleaned and freshly stacked, and nearly the whole of the copper taken out. This precipitated copper when washed, freed from fragments of iron, and calcined, contains about 75 per cent. of metallic copper. It is then bagged and forwarded to England to be refined and melted into ingots, as the high price of fuel in Spain renders it inexpedient to complete its metallurgical treatment in that country."—J. A. Phillips, F.G.S. Popular Science Review (1879), Vol. XVIII., page 113. Only about 50 per cent. of the copper present in the ore is saved by this process.

General Remarks on the "Hydro-Metallurgical" Treatment of Copper Ores.

Since "wet methods" for treating poor copper ores and the residue from the sulphuric acid burners have been received with more favour, numerous improvements in the details of the general treatment have been proposed and numerous processes have been introduced to meet the peculiarities and circumstances of each particular case.

Each of these processes usually consists of three principal operations, the treatment in one or more of these operations varying so as to produce a variety of processes.

It is unnecessary here to describe these processes* in detail, but in speaking of the general treatment, we may notice the more interesting modifications that have been proposed.

In the general treatment of ores by wet or hydrometallurgical methods three stages or principal operations are recognisable.

I. Treatment of the Ore (Generally sulphide).—In order to render the copper salts soluble in water, in dilute acid, or in a solution of some salt.

II. Solution of the Copper Salts (as chloride or sulphate), and sometimes the purification of the solution, by removing either the more valuable or the more injurious ingredients.

III. Precipitation of the Copper (usually as the metal or as sulphide), and often an after treatment of the liquors for the recovery of the other salts in solution.

The last operation or precipitation is that in which we are more particularly interested, but it seems desirable to consider something of the previous treatment of the ore and copper solution.

Treatment of the Raw Ore.—The ores usually treated are either oxides, carbonates, or sulphides, of copper. Oxides and carbonates are generally treated with a solution either of a chloride or of an acid. They are, however, sometimes roasted with the former. Sulphides are of more common occurrence, and

* The more important of these processes are described in our Standard Metallurgical Works, from which much of the following has been compiled, such as Percy's; Crookes and Röhrig's adaptation of Kerl's work; Phillips'; Greenwood's. An admirable *résumé* of the more recent "wet methods" will be found in Dingler's Polytechnisches Journal, 1879, Band. 231, pp. 254, 357, and 428. Also Proceedings Roy. Soc., New South Wales, 1876. Vol. X., page 135, reprinted in Iron, 1879, page 76, and translated into Bulletin de la Societé d'Encouragement, (1878), Series 3, Vol. V., page 612.

their treatment is more varied. The final results to be obtained in this case is either the complete expulsion of the sulphur, or, as is more usual, its partial expulsion and oxidation of the rest, thus converting the sulphide into sulphate. The simplest means by which this latter is accomplished is by *weathering* or natural oxidation, as it takes place at the mine; in the waste heaps or "attals" on the surface, and in the "stulls" and workings underground.* This is naturally a slow operation, but takes place more rapidly in ores that are not compact, and that contain a high percentage of iron pyrites, and it is greatly accelerated by the admixture of such salts as chlorides of the alkalies (soda, potash, ammonia) or alkaline earths (lime, &c.), or solutions of ferric sulphate, hydrochloric acid, or even sulphuric acid.

Owing to the tardiness of the completion of this natural process, the more rapid method of roasting is generally resorted to. This may be either with or without the addition of some reagent, and after the ore has been finely ground.

When the ore is roasted at a low heat the sulphides are converted to sulphates, and the temperature may be so arranged as to decompose the sulphates of iron without affecting those of copper. Owing, however, to the difficulty of adjusting this operation exactly and thoroughly, sulphides of copper remain unoxidized, or oxide of copper is formed; both insoluble in water, thus causing waste. The introduction in the roasting of

* The reactions that take place when pyrites is weathering are thus given by Crookes, and Röhrig. Vol. II., page 231.

"When decaying, an admixture is formed of iron pyrites, copper pyrites, arseniosulphide of cobalt and nickel (Cobalt ores of Seigen), the sulphide of iron is next decomposed:—

"$Fe\,S_2+7\,O=Fe\,O,\,S\,O_3+S\,O_3$; and

"$Fe_2\,S_3+11\,O=2\,Fe\,O,\,S\,O_3+S\,O_3$.

"An admission of air transforms the protoxide of iron into a basic salt of the peroxide and affects the chloride of iron more easily than protosulphate, chloride of calcium is therefore sometimes added to the decaying ore:—

"$2\,Fe\,O\ \ S\,O_3+O=Fe_2\,O_3\,S\,O_3+S\,O_3$.

"The formation of sulphate of copper is then facilitated by the free SO_3:—

"$Cu_2\,S+5\,O+S\,O_3=2\,Cu\,O,\,S\,O_3$.

"Finally $Co\,S_2$, $Ni\,S_2$, $Co\,As_2$ and $Ni\,As_2$ be oxidized also by the action of the free sulphuric acid forming sulphates and arseniates:—

$(Co\,Ni)\,S_2+7\,O=(Co\,Ni)\,O,\,S\,O_3+S\,O_3$.

$(Co\,Ni)\,As_2+11\,O=(Ni\,Co)\,O,\,As\,O_5+As\,O_5$.

"The latter salts are transformed by basic sulphate of iron thus:—

"$(Co\,Ni)\,O,\,As\,O_5+2\,Fe_2\,O_3\,S\,O_3=(Co\,Ni)\,O,\,S\,O_3+Fe_2\,O_3,\,As\,O_5+Fe_2\,O_3$."

some reagent (usually a chloride after a preliminary roasting of the ore) has been found therefore more generally satisfactory.

Thus, if copper pyrites be mixed with a certain proportion of lime; or a calcareous or dolomitic copper ore mixed with pyrites (*Bischof*), finely ground, moulded into bricks and roasted in a kiln, the reagents react on each other, forming sulphate of copper and sulphate and sulphide of lime. Or, when burnt or roasted pyrites is mixed with sulphuric acid, and after being moulded into bricks roasted till sulphate of iron is decomposed, the sulphate of copper formed may then be extracted with water (*De la Rue and Müller*) It has also been proposed to treat the ore in cast-iron pots with sulphuric acid at 65° C. and to boil the liquor till it thickens. The copper may then be extracted as sulphate (*Hauch*).

At the present day it is usually preferred to convert the copper into chloride, which may be accomplished either by a wet or by a dry process, the latter, especially in the treatment of pyrites cinders, being more generally adopted.

The ore having been ground and roasted is mixed with an alkaline chloride (usually common salt, but at Ocker, potassic chloride is used), and calcined, when chloride of copper and sulphate of the alkali are formed, which are dissolved out with water, but if gold or silver be present, a strong brine is used. Besides the chlorides previously mentioned (soda, potash, ammonia and lime), ferric chloride has also been proposed, as also roasting with sodic chloride and digesting with sea water and sulphuric acid (*Stella*); or moistening with hydrochloric acid and subsequent roasting.

Solution of the Copper Salts.

The solution of the copper salts is usually effected by water, but acids are used for the less soluble salts, and under certain conditions some other solutions.

Generally the ores, after the preliminary treatment, are placed in the lixiviating tanks, which have false bottoms, on which a filter of coke or of similar material is formed. The first washings are of water often heated, but sometimes the last washings of a previous supply of ore are used; when the more soluble salts are removed dilute acid is added, and finally water, the last washings being reserved for the first washings of the next supply, as there is a great advantage in having the solutions concentrated. In the accounts of the different processes, numerous appliances for

agitating the liquors, and for the introduction and removal of the solutions are described.

The following salts, amongst others, have been proposed for the solution of the copper, viz., ammonia and some ammoniacal salts for the solution of oxides and carbonates; solutions of sulphite and hyposulphite of soda; chloride of magnesia; and acid solutions of manganous chloride, the latter being a residue of the chlorine manufacturers.

Ferrous chloride in a strong brine is used in the "Hunt and Douglas" process, cupric oxide being dissolved with the separation of ferric oxide and formation of cuprous and cupric chloride, the former being kept in solution by the brine.

$$2\ Fe\ Cl_2 + 3\ Cu\ O = Cu_2\ Cl_2 + Cu\ Cl_2 + Fe_2\ O_3$$

if cuprous oxide is present metallic copper separates:—

$$2\ Fe\ Cl_2 + 3\ Cu_2\ O = 2\ Cu_2\ Cl_2 + Fe_2\ O_3 + Cu_2$$

but is re-dissolved by the cupric chloride present:—

$$Cu + Cu\ Cl_2 = Cu_2\ Cl_2$$

so that the greater part of the copper exists in the solution in the cuprous state, which requires a less consumption of iron for its subsequent precipitation.

Purification of the lixiviations is sometimes resorted to before proceeding to the precipitation of the copper. This is usually for the purpose of removing ingredients that would retard the precipitation, or be injurious to the resultant precipitate (as antimony, arsenic, lead, &c.), but is sometimes for the purpose of saving the precious metals (gold and silver) when present in sufficient quantity.

At many precipitation works where cementation is carried on, it has been remarked that often the iron is dissolved without any copper being precipitated; this may sometimes be due to free acid, but in natural solutions (as mine waters) this is not often the case. In the experiments of Napier in 1844, it was shown that no copper is deposited from a solution containing iron salts, till they were all reduced to the ferrous state, and furthermore, at Agordo in 1874, M. Zoppi found that in a solution containing ferric sulphate, on the precipitation of some of the copper it was immediately re-dissolved, and that a process of alternate precipitation and re-solution went on till all the iron present was converted to the ferrous state.

$$Fe_2\ (SO_4)_3 + Cu = 2Fe\ SO_4 + Cu\ SO_4$$

an equivalent portion of the metallic iron being consumed on each precipitation :—

$$Cu\,SO + Fe = Fe\,SO_4 + Cu_4$$

From this it appears that the chief reason for the excessive consumption of iron is the presence of these ferric salts, and furthermore, M. Zoppi found that in the presence of cast-iron this ferric sulphate is converted into ferrous sulphate, and a basic sulphate ($Fe_2\,SO_6$) that coats the metals and prevents the copper solution acting upon it. The means adopted at Schmöllnitz for overcoming this latter difficulty have been described (page 311), also that proposed for the Ovoca district (pages 308 and 309), but it is often more advantageous to get rid of these salts as much as possible. In order to precipitate them, it has been proposed to add to the solution either calcic hydrate (milk of lime) or carbonate of lime in sufficient quantity to nearly neutralize the liquid without precipitating the copper, by this means arsenic and antimony are also removed.

At Agordo the method adopted was to saturate the solution with sulphurous acid, and thus reduce the ferric salts :—

$$Fe_2\,(SO_4)_3 + SO_2 + 2\ H_2\,O = 2\ Fe\,SO_4 + 2\ \ H\,SO_4$$

Here, however, there is an introduction of free acid which would also cause an excessive consumption of iron, but on the other hand the resultant precipitate is very pure. (See Table D.)

The removal of the silver from solution varies according to the precipitant subsequently used for the copper, if that be iron, as is most general, a soluble iodide (as potassic iodide, *Claudet*) is added in sufficient quantity to precipitate the silver, and after the precipitate has subsided, the clear liquors are run off to be subsequently treated for the contained copper. It has also been proposed to blow finely divided iron dust into the liquid, till nineteen per cent. of the copper is precipitated, which then contains about eighty per cent. of the silver originally present. (*Snelus.*)

When sulphuretted hydrogen is used for precipitating the copper, the greater part of the silver is contained in the first six per cent. of the precipitate, which is accordingly first thrown down and treated separately for the contained silver (*Gibbs*).

Alkaline sulphites have also been proposed.

Precipitation of the Copper.

Copper is usually extracted from its solutions in the metallic state by cementation or precipitation on *metallic iron.* In some cases it is obtained as sulphide by precipitating with *sulphuretted hydrogen,* or some soluble sulphide. *Milk of lime, carbonate of lime,* or some other carbonates have also been proposed for precipitating it.

Cementation.—The preference given to metallic iron as a precipitant, seems to be due to the simplicity of its use and the purity of the copper obtained by this method; it being free from such deleterious impurities as lead, bismuth, &c. The chief objection to its use is its expense, especially when there is an excessive consumption, and when it is not recovered subsequently from the solutions.

The most advantageous conditions under which it could be used, should be when the consumption was the exact equivalent of the copper precipitated, and the iron recovered from solution to be again used for precipitating or for some other purpose.

From what has been stated previously, it is evident that the reaction:—

$$3\ CuSO_4 + 2\ Fe = Fe_2\ (SO_4)_3 + 3\ Cu$$

cannot take place to any great extent, as the copper so precipitated would be immediately redissolved, and therefore that the maximum result to be expected with cupric salts is:—

$$Cu\ SO_4 + Fe = Fe\ SO_4 + Cu$$

or quantities directly proportional to their atomic equivalents,—of 63·5 parts of copper for 56 parts iron;—or for each ton of iron dissolved, 22·67 cwt. of copper precipitated. In practice this is seldom attained, chiefly on account of the presence of ferric salts as previously stated. A glance at the annexed table (A) will show what a wide range there is between the maximum and minimum results.

The form of iron most generally used is cast or pig iron, and it has been found that grey pig, particularly when granulated, reacts more efficiently than white. Wrought iron, however, is more advantageously applied where the liquors are much weakened as towards the end of the precipitating process. Scrap-iron and tin clippings may be also used, the latter especially after the removal of the tin from their

surface.* Spongey iron has been strongly recommended (*Bischof Aas,* &c.) It may be prepared from the roasted residues after lixiviating, or directly from pyrites; much impurity, however, is often introduced by it,† but it might be very advantageously applied for weak liquors.

Heating the liquors has been found very advantageous in accelerating the precipitation; it is usually effected by a steam jet, at Oker-Hütte the copper is all precipitated in two or three hours, the precipitate containing 77·55 per cent. of copper and 0·10 of silver.

Sulphuretted Hydrogen.—The application of sulphuretted hydrogen for precipitating the copper is attended with the very serious objection that a very bulky precipitation is produced in a moist state generally requiring a filter-press. The presence of free acid is necessary in the solution, and for this reason, but more especially on account of the large volume of water to be treated, this precipitant seems ill adapted for treating mine drainage. We may, however, notice some of the methods proposed for its preparation, as it may be applied when iron is too costly.

At Foldal, Norway, where metal is expensive, Sinding prepared sulphuretted hydrogen by distilling fuels yielding hydrocarbons, and passing these over red hot pyrites when sulphuretted hydrogen is produced, and finely divided carbon deposited.

At the Bede Metal Works, Jarrow-on-Tyne, sulphuretted hydrogen was prepared from sulphate of soda (recovered, by evaporation, from the lixivium after the copper had been ex-

* If the tin be left on the plates half of it remains, as thin scales, which are separated on sifting the precipitate, leaving about 1·5 per cent. tin in the precipitate; this hardens the copper produced from it subsequently, and lowers the value of the precipitate.

The removal of the tin from the tin plate cuttings was effected at Alderby Edge by treating them with caustic soda. A process has been patented by Mr. E. A. Parnell to effect the same; this consists in treating the cuttings with a solution of black ash (sulphide of soda), and about three per cent. of sulphur. This heated and concentrated to 25° Twaddle removes the tin almost immediately in solution, from which it is recovered as oxide on calcining, the sulphide of soda being converted to sulphate, is removed on washing and crystallized out as glauber salts. The cuttings contain a small quantity of tin rendering the iron very brittle when worked up into blooms or bars, but this may be completely removed by a solution of calcic chloride.

† If the ochre were recovered from solution after the removal of the copper, a very pure form of this reagent might be obtained.

tracted) which was balled with small coal and furnaced forming sodic sulphide; this was dissolved out with water, and into the solution a current of carbonic dioxide (obtained from the combustion of coke) was passed, carbonate of soda was thus formed and sulphuretted hydrogen given off (*Gibbs*).

Sulphuretted hydrogen has also been prepared from barium sulphide (*Wagner.*)

Calcic sulphide has been proposed for precipitating the copper, and was used in Escalle's process as worked near Marseilles, the copper being present as chloride; in a solution of sulphates, however, the precipitate would be largely contaminated with sulphate of lime. For the same reason carbonate or hydrate of lime would be objectional, especially as, unless the solution were very pure, many other metals would be precipitated along with the copper.

At the Royal Works of Mülden and Halsbrücke, near Friberg, sulphuretted hydrogen is produced by the action of sulphuric acid on sulphide of iron, the latter being prepared by roasting together furnace clay and iron pyrites free from blende, the sulphate of iron formed being subsequently crystallized out.

Several electrical methods have been proposed for the extraction of copper from its solutions. Becquerel (1835—1840) made numerous trials, but their aim was more for saving the silver; in these, couples were formed of various combinations, the negative poles were immersed in porous diaphragms filled with salt solution, which were immersed in the liquors, the other pole being in direct contact with the liquid.

Patera's method was for extracting the copper from poor cementation waters. In cells of clay or fir-wood were placed iron plates, that were connected with small pieces of coke, which formed the negative electrode, a salt solution being used to produce the action.

Keith's method* consists in filling large porous cells (32 inches high by 12 inches diameter), with a solution of sulphate of iron (free from copper), and scrap-iron; these cells are placed in large barrels, through which the copper solution flows, in which a copper plate is immersed that is connected with the cells externally by a wire; the copper is deposited on the plate in a pure and

* See "Engineering and Mining Journal," 1877, page 366.

coherent form, while the iron in the cell passes into solution; when the sulphate of iron solution becomes too concentrated it is diluted and fresh iron added. The copper deposited is the exact equivalent for the iron dissolved, viz., 63·5 copper for 56 of iron. The cost of extraction is about one cent. per pound.

Dynamo-electricity has been tried at Ocker in Germany, where a Siemens-Alteneck machine supplies the current to ten or twelve precipitating cells, which deposit about fifty pounds of copper in twenty-four hours, that contains only about 0·5 per cent. of impurity. (See note added in press.)

The liquors from which the copper has been extracted generally contain large quantities of sulphates of iron and alumina, besides small quantities of zinc and manganese. Much of the iron, present as ferrous sulphate, separates out by natural oxidation if the solution is exposed for a time with constant agitation, basic salts being deposited and the acid liberated. (*Wagner*).

Cementation at Agordo.

At Agordo,* the copper solution is obtained from a poor pyrites containing one and a-half per cent. of copper, which is first subjected to a process of kernal roasting, which results in the formation of a rich kernal of sulphide of copper, containing from twenty to fifty per cent. of copper, surrounded by an envelope of oxides and sulphates of iron and copper; this is broken off, the kernals are smelted for copper, but the shells are treated with water, the lixivium run to the precipitating vats containing cast-iron, heat is applied for the double purpose of concentrating the liquors and accelerating the precipitation, this is effected in two different forms of arrangement, the one is a large wooden vat containing a leaden vessel (" chambre de plomb "), in which a fire is lighted; the other is an ordinary reverberatory furnace, the bed of which is converted into the precipitating tank, the flame passing along the surface of the liquors.

Cast-iron is piled in these vessels and the liquors run in, heat is then applied, and the temperature maintained at 62° or 63° C.

* For details of these workings, see "Annales des Mines," 1855, 5th Series, Vol. viii., pp. 407-493. "Annales des Mines," 1876, 7th Series, Vol. ix., pp. 190-200.

(about 144° F.), till the waters become yellow, this occurs in about twelve hours, the bluish colour disappears, and the boiling is limpid, it is then allowed to settle for a day, the clear liquors are drawn off and the turbid run to settling tanks, where the suspended material deposits, this consists of basic salts of iron, impurities from the cast-iron, and about ten per cent. of copper in fine powder, and is locally termed "brunini."

The iron in the precipitating tanks is washed with water, and the adherent copper removed, when it has deposited the waters are drawn off, this portion of the precipitate is termed "grassure," and contains about 59 per cent. of copper.

In 1874 the method of procedure was somewhat altered, as it was found that the consumption of iron was excessive, and that the insoluble basic salts of iron that were produced lowered the quality of the cement copper. Both these defects being due to ferric sulphate in solution, steps were taken to reduce the solution. This was effected by saturating the solution with sulphurous anhydride (SO_2) in the following manner:—The liquors were passed down a chimney and into a tank, through both of which the gas (derived from the roasting of the ore) was passing in the opposite direction, so that ferrous sulphate and free sulphuric acid were formed. The reduced liquors were run on to cast-iron in tanks, that could be heated by a peat fire, the temperature at first is 34° R. (about 109° F.); in the early stages hydrogen is given off till the metals become coated with copper, the temperature is subsequently raised to 38° R. (118° F.), and finally to 40° R. (122° F.), when more iron is added to complete the precipitation; when the whole has been allowed to settle for twenty-four hours and the temperature has become reduced to 35° R. (about 111° F), the clear liquors are run to crystallizers where sulphate of iron is recovered. The precipitated copper is found in two conditions, about 70 per cent. is found in compact scales adherent to the iron, and is almost pure, while about 30 per cent. occurs in a powder containing arsenic and ferric oxide in considerable quantities. (See Table D.)

Process of Sterry Hunt and Douglas.

In the process of Hunt and Douglas,* the solvent used for lixiviating is a solution in brine of ferrous chloride ($Fe\ Cl_2$), this decomposes cupric oxide forming cuprous and cupric chloride, which pass into solution (the former, although insoluble in water dissolves in brine) while ferric oxide separates.

The dissolving bath is made by adding 120 parts of salt (or 112 parts of calcic chloride), and 280 parts of sulphate of iron to 1,000 parts of water, then 200 parts of salt are added, ferrous chloride is formed, with this the crushed and roasted ore is treated when the cupric oxide is converted into chloride

$$3\ Cu\ O + 2\ Fe\ Cl_2 \quad Cu\ Cl_2 + Cu_2\ Cl_2 + Fe_2\ O_3.$$

but if cuprous oxide be present, metallic copper is deposited,

$$3\ Cu_2\ O + 2\ Fe\ Cl_2 = 2\ Cu_2\ Cl_2 + Fe_2\ O_3 + Cu_2$$

the solution, when the reaction is complete, is drawn off and treated with scrap-iron to precipitate the copper, ferrous chloride being thus reformed, so that the liquors may be used repeatedly to dissolve the copper from the roasted ore.

At the Knob Copper Reduction Works, Carolina, the crushed and roasted ore is treated with the solution of ferrous chloride and salt for eight hours at 160° F., it is then allowed to settle for four hours, when the clear liquors are run to the precipitating tanks (the muddy portions having been allowed to subside), where they are treated with scrap-iron for twelve or eighteen hours at 160° F., when all but a trace of copper has been precipitated, the liquors are then run on to a fresh supply of roasted ore.

This process seems to be specially applicable to ores containing oxide of copper, it may, however, be applied to carbonates and sulphides after grinding and roasting, the objection has been raised that poor ores will not bear this preliminary treatment. But it seems to have been successfully applied at the Ore Knob Works and at Chile.

* For a full account of this process, see "Engineering," Vol. xxii., page 419¾; "Chemical News," (1870), Vol. xxi., page 177. For a description of the Ore Knob Mine and the working of the process, see "Transactions American Institute of Mining Engineers," Vol. iii., page 391. Other improved processes are described in "American Journal of Science," Vol. xliii., page 305, and one by W. A. Dixon, F.C.S., "Journal Royal Society," New South Wales, 1877, Vol. xi., pp. 93–111; and "Chemical News," 1878, Vol. xxxviii, pp. 281, 293, 301.

Conclusion.

From the account that has been given of copper precipitation as practised at the Ovoca Mines, and the short *résumé* of the more improved processes that have been tried at other mines, and in the humid treatment of poor copper ores, it seems that the resources of this method of treatment have not been exhausted at the Ovoca mines, for, not only is the copper precipitate obtained in an impure state with an excessive consumption of iron, but the copper is not completely extracted from the waters, and all the sulphate of iron is allowed to run to waste; besides, no attempt is made to enrich the waters, which, since active operations in the mines have, in a great measure ceased, are gradually becoming weaker, although poor copper ores, ranging up to two or three per cent. of copper are to be found in the mines.*

Regarding the impure state of the copper precipitate obtained with an excessive consumption of iron, it has been pointed out that both these defects are principally due to the presence of ferric salts in the solution which not only act directly on the *cast iron,* thus :—

$$(\alpha.)\ Fe_2\,O_3\,(SO_3)_2+Fe_2+2H_2\,O=Fe_2\,O_3\,SO_3+2Fe\,SO_4+2H_2$$

some of the iron passing into solution, and a basic sulphate of iron (an ochre) depositing: but also the copper that is precipitated according to the reaction

$$(\beta.)\ Cu\,SO_4+Fe=Fe\,SO_4+Cu$$

is redissolved by these ferric salt, thus :—

$$(\gamma.)\ Fe_2\,(SO_4)_3+Cu=2Fe\,SO_4+Cu\,SO_4$$

a fresh quantity of iron being dissolved on its reprecipitation; these reactions proceeding alternately till all the ferric salts become reduced. Several methods that may be adopted for the

* In the "backs" of the great pyrites lodes there are immense quantities of poor copper ores (principally the black and grey ores of copper mixed with pyrites and other sulphides), which on the admission of air and moisture undergo rapid decomposition, the copper and some other substances being rendered soluble. At East Cronebane and Connary there is a large supply of these easily oxidizable ores, giving in some places sections of ore from 6 to 8 fathoms wide and averaging $1\frac{3}{4}$ to 2 per cent. of copper. These ores occur in a soft unctuous clay which prevents the water from percolating through, so that the ores are preserved in an undecomposed condition till opened up.

Besides these friable ores there are others in the lode more compact, but which also contain much pyrites and undergo decomposition on exposure. There are also some hard and very complex ores such as the "Kilmacooite" or "bluestone."

Descriptions of these mines and minerals will be found in "Records of the School of Mines," Vol. I., Part 3, by Professor Warington W. Smith, M.A., and in "Notes on the Ancient and Recent Mining Operations in the East Ovoca District," by P. Argall, Proc., R.D.S., n.s., Vol. II., p. 211.

reduction of these salts have been already mentioned, but in addition it may be suggested that the siftings referred to at page 306 might be utilized for this purpose, as both the copper and iron fragments would assist in reducing the solution, according to the reactions just given, the copper at the same time being extracted from the siftings.

For the complete extraction of the copper from the solutions it appears that either the excess of iron salts must be first got rid of, or that these salts must be completely reduced to the ferrous state.

Respecting the waste of the sulphate of iron this not only represents a loss, but is also a source of injurious impurity to the river into which it falls, and which is polluted to such an extent as to be poisonous, so that no fish of any kind can live in this portion of it, consequently in the head-waters only, non-migratory fish (as brown trout, char, &c.), are now to be found.

The more usual method for the recovery of the sulphate of iron is evaporation and crystallization of the salts, here, however, this seems inapplicable on account of the scarcity of fuel and the large volume of weak liquors to be treated. Some precipitant should therefore be adopted, and the most advantageous would probably be either lime or limestone, the precipitate obtained by the first would be an ochre largely contaminated with sulphate of lime, but if the latter were used, it is probable the method of working could be so adapted as to separate the ochre in a great measure from the sulphate of lime.

As to enriching the solutions; "Kernal roasting" as adopted at Agordo, or as formerly practised at some of these mines during Weaver's management (1787–1811) appears to be preferable, but some other system of roasting might be attempted, or, as many of the ores here contain much pyrites they undergo weathering or natural oxidation most rapidly (especially the soft and friable ores) and this decomposition might be greatly accellerated by employing some of the reagents mentioned at page 313.

At Agordo (Venetian Alps); Rammelsberg (Hartz); Schmöllnitz (Hungary); and at Fahlun (Sweden); where there are deposits apparently very similar, and containing similarly mixed ores; peculiar modifications are adopted for working up these ores, and it appears very possible that some peculiar method might be adopted profitably at the Ovoca mines.

TABLE A.—Showing the amount of Precipitate and the amount of Copper produced by the consumption of one ton of Iron at different Mines and Metallurgical Establishments—quantities stated in hundred-weights.

Number.	LOCALITY, &c.	Date.	Amount of Precipitate in cwts. for ton of Iron.	Copper in cwts. for ton of iron consumed.	Nature of Precipitant used.	REMARKS
I.	Mona Mine, Anglesea, .	1832 1866	20·23	1·96	Scrap iron and tin plate, . .	Lixivium from calcined ore and drainage from mine and waste heaps, treated in a series of large pits. Page 310.
II.	Pary's Mine, Anglesea, .	1844	—	1·83 2·00	Old iron, . .	Mine drainage passed through a series of large pits.
III.	Pary's Mine, ...	1862 1866	11·26	2·65	(Scrap iron,) . .	Mine drainage and lixivium from calcined ore, treated for ten weeks in large pits.
IV.	Cronebane Mines, Wicklow,	1862	8·00	2·80	Wrought iron, .	Mine and surface drainage during active operations, treated in inclined launders.
V.	Lucençia Mine, Huelva, Spain, . . .	1859	4·00 5·00	2·00 3·00	Pig iron, . .	Mine water passed through heaps of calcined ore, and treated in large pits. Pages 310 and 311.
VI.	Great (Gwennap) Adit, Cornwall, . . .	Since 1854	8·00 10·00	3·12 4·00	Scrap iron and tin plate, .	Mine drainage of large area, treated in pits (strips) along the stream. Page 310.
VII.	Connary, Wicklow, . .	1860 1861	9 67	4·26	Scrap iron and tin plate, . .	Mine drainage passed through horizontal tanks and inclined launders. Page 304.
VIII.	Devonshire Great Consolidated Copper Mines,	1866	10·00 11·04	5·00 5·13	—	Drainage of mines. Page 310.
IX.	Wheal Agar, Cornwall, .	—	15·00	4·50 5·25	—	Adit drainage of an abandoned mine. Page 310.
X.	Agordo, Venetian Alps, .	1874	—	5·71 6·25	Cast iron,	Lixivium from shells produced by "kernal roasting," and heated to 34° — 40° R. in tanks. Pages 320 and 321.
XI.	Schmöllnitz, Hungary, .	1860	—	6·66	Cast iron,	Drainage of active mine, treated in inclined launders. Page 311.
XII.	Ballymurtagh, Wicklow, .	1852 1861	16·00	7·12	Scrap iron, .	Mine drainage during active working, treated in steeply inclined launders. Page 304.
XIII.	Schmöllnitz, Hungary, .	1859	13·71	7·69	Wrought and cast iron.	Mine drainage treated in launders, inclined and vertical. Page 311.
XIV.	Agordo, Venetian Alps,	1875	9·98	7·84	Cast iron, .	Lixivium as in No. X., but after reduction with sulphurous acid. See pages 320 and 321.

[*continued.*

TABLE A.—Showing the amount of Precipitate and the amount of Copper produced by the consumption of one ton of Iron at different Mines and Metallurgical Establishments—quantities stated in hundred-weights—*continued.*

Number.	LOCALITY, &c.	Date.	Amount of Precipitate in cwts. for ton of Iron.	Copper in cwts. for ton of iron consumed.	Nature of Precipitant used.	REMARKS.
XV.	Agordo, Venetian Alps, .	1855	15·73	7·91	Cast iron, . .	Lixivium from "kernal roasting," heated to 62° — 63° C. in "chambre de plomb." Pages 320 and 321.
XVI.	Rio Tinto, Huelva, Spain, .	1859	92·16	9·22	Cast iron, . .	Lixivium from calcined ore, poor portion of precipitate held in suspension, treated in pits. Pages 310 and 311.
XVII.	Rio Tinto, Huelva, Spain, .	1859	16·75	9·22	Cast iron, . .	Lixivium from calcined ore, treated in pits, precipitate adherent to iron. Pages 310 and 311.
XVIII.	Agordo, Venetian Alps, .	1855	19·76	9·44	Cast iron, . ,	Lixivium from shells produced in "kernal roasting," heated to 62° — 63° C. in "chambre de reverbere."
XIX.	Santiago Mines, Cuba, . .	1844	15·54	10·88	Scrap iron, . .	Weak mine drainage percolating through irons placed on racks in large tanks.
XX.	Cronebane, Wicklow, . .	1878	21·00	14·7	Tin-plate cuttings,	Rich mine waters, treated in launders. Page 306.
XXI.	Santiago, Cuba, . . .	1844	20·00	15·00	Fresh bar iron, .	Weak mine waters, treated as No. XIX., but with clean iron.
XXII.	Twiste, Waldeck, . .	—	—	16·00	Scrap iron, . .	Lixivium from treating carbonates with hydrochloric acid.
XXIII.	Connary, Wicklow,	1838 1839	—	19 94	Wrought iron and tin plate, . .	Mine waters in winter treated alternately in horizontal tanks and inclined launders. Page 306.
XXIV.	Cronebane, Wicklow, . .	1787 1811	—	20·6	Plate and scrap iron, . .	Mine drainage and lixivium from "kernal roasting" during Weavers' management. Geo. Soc. Transactions, Vol. v., p. 218.
XXV.	Santiago, Cuba, . . .	1844	24·00	21·48	Fresh bar iron, .	Rich mine water, treated as No. XIX., but with clean bar iron.
XXVI.	Theoretical result and Keith's Electrical, .	—	22·67	22·67	Clean iron, . .	Result for cupric salts—$Cu\ So_4 + Fe = Fe\ So_4 + Cu$.
XXVII.	Napier's Electrical, . .	—	—	23·77	Clean iron, . .	See "Philosophical Magazine," Vol. XXIV., p. 365.
XXVIII.	Cronebane, Wicklow, .	1751	39 5	31·6	Bar iron, . .	Apparently inaccurate. See page 303.
XXIX.	Hunt and Douglas process—Practical result. See page 322.	1870	—	33·33	Scrap iron, . .	Copper mostly in cuprous state. $Cu_2Cl_2 + Fe = FeCl_2 + Cu_2$.

TABLE B.—Analyses of the principal constituents of Ballygahan Water before and after Cementation, in parts per 100,000, by G. A. Kinahan.

—	Before Cementation.	After Cementation.
Ferrous Oxide, . .	81·81	94·75
Ferric Oxide, . .	4·30	6·70
Cupric Oxide, . .	9·32	1·91
Sulphuric Acid, . .	634·26	642·34
Manganous Oxide, .	2·30	2·50
Zincic Oxide, . .	1·20	1·80
Total, . .	733·19	750·00

TABLE C.—Analyses of the Mine Waters of Schmöllnitz before and after Cementation, in Vienna, lbs. per cub. ft.: by Lill von Lilienthal.

—	Before Cementation.	After Cementation.
Ferrous Sulphate, .	0·331	1·025
Ferric Sulphate, . .	0·458	0·011
Sulphate of Copper, .	0·081	0·005
Sulphate of Zinc, . .	0·049	0·045
Sulphate of Aluminium,	0·497	0·448
Sulphate of Lime, . .	0·063	0·060
Sulphate of Magnesia, .	0·303	0·288
Total, . .	1·785	1·882

TABLE D.—Analyses of the Lixivium and Cement Copper at Agordo: by M. de Hubert.

Reduced Lixivium.	Before Cementation.	After Cementation.	Products of Cementation.	Cement Copper in Scales.	Cement Copper in Powder.
Cuprous Oxide, . .	1·38	0·06	Copper, ...	87·41	57·95
Ferrous Oxide, . .	6·91	8·72	Ferric Oxide, . . .	3·40	10·95
Oxide of Zinc, . . .	1·78	2·32	Oxide of Zinc, . .	0·50	1·78
Alumina, ...	0 66	0·74	Alumina, . . .	0·25	0·33
Arsenious Acid, . .	0·24*	—	Lime, ...	2·00	1·80
Sulphuric Acid (combined),	12·61	14·15	Sulphuric Acid, . .	1·12	2·57
Free Sulphuric Acid, .	2·08	0·63	Arsenic, ...	0·69	4·93
Water, ...	73·68	72·48	Water, ...	1·00	3·83
			Insoluble residue, . .	3·50	12·10
Total, . . .	99·34	99·12	Total, . . .	99·87	96·24

* Equivalent to 0·183 of Arsenic.

NOTE ADDED IN PRESS.—October 16th, 1882.

From Dr. C. W. Siemens' Address to the British Association, 1882.

"The deposition of metals from their solutions is perhaps the oldest of all useful applications of the electric current, but it is only in very recent times that the dynamo current has been practically applied to the refining of copper and other metals, as now practised at Birmingham and elsewhere, and upon an exceptionally large scale at Ocker, in Germany. The dynamo machine there employed was exhibited at the Paris Electrical Exhibition by Dr. Werner Siemens, its peculiar feature being that the conductors of the rotating armature consisted of solid bars of copper 30 mm. square, in section, which were found only just sufficient to transmit the large quantity of electricity of low tension neccessary for this operation. One such machine consuming 4-horse power, deposits about 300 kilogrammes of copper per 24 hours; the motive power at Ocker is derived from a waterfall."

DESCRIPTION OF PLATES.

Plate XXII.

Figs. 1 and 2.—Represent diagramatically the arrangement of launders (L L^1) and hutchs (H H^1) employed at some of the Ovoca mines. The waters entering at (L) flow along the launders (l_1 l_2 l_3 ...... L^1) the bottoms of which are strewn with fragments of iron, &c.

When being cleared out a movable partition in the side of the hutch at (*a*) is taken up and placed across the launder as shewn by the dotted lines, that portion of the launder above this is then brushed down and the metals agitated with a rake, the water and suspended copper passing into the hutch at (*a*) in which the copper accumulates while the water flows back to the launder at (*b*). This portion being finished, the same operation is repeated for the next hutch and so on through the whole series.

When the suspended copper has subsided in the hutch the supernatant water is drawn off either through a plughole in the side or by a siphon.

Figs. 3 and 4.—Represent in section and plan the launders used underground in Cronebane.

The water enters at (A) passes down through the metals and rack (*r*) (on which the irons are piled) under the movable partition (*m*) and ascending through the rack (r^1) (and irons) it passes over the fixed partition (*f*) into the next compartment (B) in the direction indicated by the arrows.

The irons in these launders are agitated with an iron rake once a day when the precipitate falls off and settles in the space (S) from whence it is collected once a quarter or oftener if requisite.

Plate XXIII.

Fig. 1.—Represents the cross section of a drift in which there are placed an inflowing launder (I), and exit launder (E). Above these is placed the wire tramway (R) supported on iron supports (S) and which carries the small waggon (W).

Fig. 2.—Is a side view of the waggon with the carriage that supports it on the wire rope.

Fig. 3.—Is an enlarged end view of the supporting strap (H) showing the wheel in position on the rope (R) the latter being held by a support (S) driven into the side of the level.

Fig. 4.—Is the form of support that is used to suspend the wire rail from the roof of the level.

Fig. 5.—The cross section of an adit level where the launder (L) is placed in the centre supported on transverse sleepers (S), the sides being supported by the blocks (B) that carry the rails (R). The waggon (W) thus passing above the launders. A channel (C) is left underneath for flood waters, &c.

XXIX.—SOME NOTES ON THE GEOLOGY OF BRAY HEAD, WITH A GEOLOGICAL MAP AND SECTIONS. By GERRARD A. KINAHAN. Plates XXIV., XXV., XXVI.

[Received August, 1882.]

While studying Geology, some few years ago, at the College of Science, Dublin, in order to familiarize myself with field Geology and practical work, I examined and mapped the more continuous sections of the Cambrian Rocks exposed on Bray Head. Since then I have examined and mapped the surface of other parts of the hill; and, as a geological map with some sections of this district may be of interest to the Society, I have been induced to lay it before them, especially as it will be more accessible in their Proceedings than the map of the Geological Survey. I have carefully compared them together, and find them to agree in the main. In this map, however, more breaks have been inserted; these cannot be taken as absolutely correct, but are what appeared to me, when on the ground, to be best calculated to explain the peculiarities, especially those of the quartz rocks.

As the rocks of this area have been the subject of many papers, and of much discussion,* I have refrained from giving a

* Such as:—"On the Rocks of Bray Head." Prof. Oldham, Journal Geo. Soc. Dublin, vol. iii., p. 60.

"Quartz Rocks of Bray Head and Howth." John Kelly, Esq., Journal Geo. Soc. Dublin, vol. v., p. 237.

"On the Structure of the North-Eastern part of Wicklow." By J. Beete Jukes and Andrew Wyley, Esqrs., Journal Geo. Soc. Dublin, vol. vi., p. 28.

"On Annelloid Tracks in Rocks of Bray Head." By J. R. Kinahan, M.B., Journal Geo. Soc. Dublin, vol. vii., p. 184.

"On the Organic Relations of the Cambrian Rocks of Bray (Co. Wicklow) and Howth (Co. Dublin), with Notices of the most remarkable Fossils." Professor Kinahan, Journal Geo. Soc. Dublin, vol. viii., p. 68.

"On Haughtonia, a new genus of Cambrian Fossils." By Professor J. R. Kinahan, M.D., F.L.S., Journal Geo. Soc. Dublin, vol. viii., p. 116.

"The Genus Oldhamia: its characters, probable affinities, modes of occurrence, and a description of the nature of the localities in which it occurs." By J. R. Kinahan. Trans. Royal Irish Academy (Science), vol. xxiii., p. 547.

"On a Trap Dyke at Bray Head, Co. Wicklow," by W. H. Stackpoole Westropp, M.R.I.A., Journal Royal Geo. Soc. Ireland, vol. i., p. 149.

"On the Lower Palæozoic Rocks of the South-East of Ireland and their Associated Igneous Rocks." By J. Beete Jukes, M.A., F.R.S., &c., &c., and Rev. Professor Haughton, M.A., F.T.C.D., F.R.S. Trans. Royal Irish Academy, vol. xxiii., p. 563.

detailed description of them. I have, however, with great diffidence, offered a few suggestions which may contribute towards a new explanation of some of the obscurities in the geological structure of the hill.

The rocks in this area, which are considered to be typical Irish Cambrians, consist of an immense thickness of green and purple grits and slates, with large masses of quartz rock. The slates and grits, although often twisted and folded, and sometimes even inverted (see Plate XXVI., figs. 3 and 4), have a tolerably regular general strike nearly N.E. and S.W., with a general dip to the N.W. An observer crossing the summit of the hill at right angles to the strike of the strata, will meet with several masses of quartz rock which, although much broken up by small breaks, form more or less continuous bands, which seem to be conformable to the adjoining strata, and to form with them a continuous sequence. However, on examining the sections to the west and east (along the Delgany road and the railway), only two of these masses will be met with, and in these two there are such striking similarities, that very possibly they are portions of the same reef, which has been brought twice to the surface by extensive faulting.

In the lands of Bray Head House, on the northward slope of the hill, a large mass of quartz rock (A.) appears east of the House. This seems to be a bed that is conformable to the strata, the northern portion of which rests on the slope of the hill, with its upper surface exposed; towards the east, however, it curves sharply, and being doubled on itself, the edge of the bed only, appears a little to the south. Probably it is the same reef that is seen further to the S.W. (A.'), at the boundary between Bray Head and Ballynamuddagh.

Southward of these exposures is the reef (B.B′) extending from the shore across the northern summit of the hill, in a slightly curved N.E. and S.W. broken line into Kilruddery demesne, east of the house. In the section exposed by the railway cutting this

"Memoirs Geo. Survey of Ireland," sheets 121 and 130. By J. Beete Jukes, M.A. F.G.S., and G. V. Du Noyer, M.R.I.A.

"Weaver's Geological Relations of the East of Ireland," Trans. Geo. Soc., series 1, vol. v.

"The Physical Geology of the neighbourhood of Dublin." By Rev. M. H. Close, F.G.S., Journal Royal Geo. Soc. Ireland, vol. v., p 49.

"Physical Geology of Ireland," p. 8. By Edward Hull, LL.D., F.R.S.

"Manual of the Geology of Ireland," pp. 13, 35, 196. By G. Henry Kinahan, M.R.I.A.

quartz reef appears much thicker than it is in reality, as it is crossed by a break, by which it is doubled upon itself. Turning somewhat towards the south it becomes less compact on its under side; but the sequence south of this is indistinct, as the ground is much broken. On the north or upper side it is overlaid by grits and slates that are quite conformable to it. However, on looking up the slope of the hill, these appear to strike away from the quartz reef, which forms a very conspicuous feature right across the summit of the hill. South-east of this ridge there is a marked hollow across the hill, on the opposite side of which, in the lands of Ballynamuddagh, numerous small masses of quartz rock appear, which seem to represent one band of quartz rock much twisted and broken. This to the west disappears under the drift, while to the east it is cut off by a series of N.W. and S.E. breaks.

Still further south there is the second reef* (E.E′), forming a conspicuous ridge, and the highest point on the hill (793 feet). It extends from the Brandy Hole along the bounds of Ballynamuddagh and Rathdown Upper, towards Windgate. Like the main reef (B.B′) further north, it is much broken up by faults. In the section as seen on the shore it is overlaid by grits and slates having a reddish burnt appearance. The under surface of the reef has several peculiar rounded masses projecting from it, and rests on a comparatively soft, reddish sandy bed, under which are slates and hard quartzose grits. Some distance below these a bed of greenstone appears in the cliffs and railway cutting, and can be traced up the steep slope of the hill for some distance, but is lost under the drift towards the top, and could not be found further to the west.

The grits and slates on this southern slope are much twisted and folded, being repeated many times, as may be seen along the shore and railway cuttings (Plate XXV.), especially at the most southerly point of the head, beyond which, towards Greystones and towards the west, they pass under a deep covering of drift that extends for some distance up the slopes of the hill.

* The surfaces of these reefs are in many places well glaciated. The striæ being well preserved on the quartz rock, numerous other glacial evidences are to be found over the hill, such as transported blocks. The projecting headlands along the shore-line are also striated in some cases on highly-inclined or vertical faces.

It has been already stated that it seems very possible that the two principal reefs crossing Bray Head are disconnected portions of the same. This is only a surmise on which very little direct evidence can be produced. Between the two reefs there is a great similarity, and the sequence of rocks in connexion with both presents a general similarity. However, below the Brandy Hole reef there is the greenstone dyke that is not to be found below the northern reef. This may be due to the dyke being a later intrusion, probably after the disconnexion had occurred, and this is supported by the fact that the dyke is not to be found under the western portion of the Brandy Hole reef.

At first sight there may appear to be a difficulty in detecting any line along which such a fault could cross the hill. But on closer examination, it appears very possible that the outcrop of this fault, which fault would dip south at a low angle, runs nearly parallel to that of the strata and along the hollow south of the more northerly reef, and instead of extending to the shore line at Bray Head, it turns south down the slope of the hill towards the Brandy Hole; this sudden flexure being caused by the breaking up of the strata along the numerous joints and breaks that cross their strike, and the subsequent removal of that portion lying above the plane of the main fault and east of some of the more marked of these breaks. The bearing of this main fault would be about E. and W., while it would be along it that the cave known as the Brandy Hole extended. On the westward slope of the hill, the sections and evidence in connexion with this fault are very obscure, as the glacial drift extends for some distance up the slopes of the hill, and above this there is in many places a thick covering of meteoric drift.

DESCRIPTION OF THE PLATES.

Plate XXIV.

A.—The northern exposure of the upper quartz reef.

A′.—Supposed detached portion of the northern exposure of the upper quartz reef.

B B′.—Northern exposure of the lower quartz reef in places broken up and displaced by transverse faults.

C D E.—Supposed outcrop of the main fault (Brandy Hole fault), a down-throw to the south, which brings down the quartz reefs, thus causing them again to appear at the surface further to the southward.

C D.—Line of outcrop along the general strike of the strata, marked by a hollow filled with drift and peaty accumulations.

D E.—Line of outcrop along the principal breaks that cross the strata, marked by steep and abrupt ground south-west of this line.

E C.—Probable line of strike of the main fault.

D D′.—The southern exposure of the upper quartz reef A due to the southward down-throw of the main fault. The reef is much broken up and displaced by transverse faults.

D″.—Detached portions of the Ballynamuddagh quartz reef, whose relations to the reef D D′ are obscure.

E.—The southern exposure of the lower quartz reef B B′ due to the southerly down-throw of the main fault. The reef is broken and displaced by transverse faults.

Plate XXV.

Section along the coast line from South to North. In this section the upper quartz reef is not seen, while the south and north exposures of the lower quartz reef appear respectively at E and B.

Plate XXVI.

Fig. 1.—Section of the northern portion (B) of the lower quartz reef, as seen on the west side of the railway cutting.

Fig. 2.—Plan of the northern portion (B) of the lower quartz reef, between the railway and the coast line. The quartz to the south-east has been removed along a large joint, so as to expose the underlying slates and grits on the shore.

Fig. 3.—Sketch section of the rocks along the west side of the railway cutting at Bray Head, illustrating the manner in which the rocks are twisted, broken, and displaced by the numerous fault lines—line *a b* indicates the site of the cliff path.

Fig. 4.—Plan of the rocks between the railway and coast line at Bray Head.

XXX.—GLACIAL MORAINES ON MOUNT LEINSTER, COUNTIES WEXFORD AND CARLOW. By G. H. KINAHAN, M.R.I.A., &c. PLATES XXVII., XXVIII., AND XXIX.

(Read, June 19th, 1882.)

In the coom at the head of Glen Clody, situated on the north-east side of Mount Leinster, there are remarkable traces of a glacier, to which I would direct the attention of the Society.

These traces consist of two long lines or walls of heaped-up granite blocks, which, from their character and the way in which they run, can be accounted for only by their having been deposited round the edges of a small glacier at two different stages of its development, at each of which it must have had very well-defined limits. The general appearance of the coom is represented by the sketch, Plate XXVII., while Plate XXVIII. shows the extent of the glacier at the two stages of its development; as indicated by the two lines of blocks, the blue representing the glacier at its last stage.

The south-east face of the north-west part of the inner moraine, Plate XXVIII. C., which is formed of huge blocks, is remarkably grand; being straight, nearly perpendicular, and from 20 to 40 feet high; it is represented in Plate XXIX.

The line of blocks outside the glacier, as represented in Plate XXVIII., indicates its original and greater extent.

The moraines in question are particularly interesting, for this reason that they are so different from the general type of corry moraines, of which there are so many in this country. They are almost entirely composed of large blocks without small detritus mingled with them; whereas ordinary corry moraines, though containing and carrying large blocks, have so much small debris mixed with these that they can act as dams to the tarns, or small lakes, which sometimes occupy the corry. I believe that there has been a peculiarity in the mode of their formation, apparently illustrated by what I have observed to take place at the present day in the same district.

As has been already pointed out in my "Geology of Ireland," page 311, in some winters large snow-drifts are formed in the cooms of the Lugnaquillia Mountains; and when the surfaces of these drifts become frozen over, all blocks that fall from the

adjoining cliffs on to them slide off, and form at their margins moraine-like accumulations; from which I would suggest that an operation somewhat similar, but on a much larger scale, took place in the Craan Coom on Mount Leinster, the blocks in the marginal heaps having partially slid down over the glacier, and been partially carried on the downward creeping mass of ice from the granite cliffs between A and B, Plate XXVIII., as indicated by the lines of blocks on the glacier, the marginal cliffs being more than 500 feet higher than the highest blocks, and over 1,000 feet above the lowest blocks; the space that was occupied by the glacier during the time of its smaller and later development, is comparatively free from blocks.

This coom gets the name "craan" from the numerous blocks in it. The N.W. coom of this mountain on its county Carlow side, in which there are no very striking indications of glacial action, is called Coolasnaghta, or the snow-corner.

In summer the lines of blocks are much concealed by the remarkably tall bracken growing about and among them; they are therefore best seen in winter and early spring.

XXXI.—ON THE DEFINITION OF FORCE AS THE CAUSE OF MOTION, WITH SOME OF THE INCONVENIENCES CONNECTED THEREWITH. BY REV. MAXWELL H. CLOSE, M.A.

[Received August, 1882.]

FORCE is still generally declared to be that which produces motion or momentum in a mass. It will be sufficient to quote two of the latest and most authoritative statements to this effect both of which are given in the most comprehensive form :—

"*Definition of Force.*—Force is whatever changes or tends to change the motion of a body, by altering either its direction or its magnitude."—(Clerk Maxwell, *Theory of Heat*, p. 83.)

"The definition of Force × × may thus be given.—Force is any cause which alters or tends to alter a body's state of rest or of uniform motion in a straight line."—(Tait, *Recent Advances in Physical Science*, p. 16.)

We have the very same position in Thomson and Tait's "*Treatise*" and "*Elements of Natural Philosophy*;" but it is not there so completely expressed in a single sentence.

It is most respectfully submitted that this definition is inconsistent with the meaning of "Force" in modern kinetics, as well as in statics and energetics, where it seems to be altogether out of place. Perhaps some might prefer to say that the following, if correct, proves rather that "force" is still used to mean two totally different things, viz.: force proper and impulse. This, however, comes very nearly to the same as what we have just said. Such looseness in the employment of so important a word is equivalent to an objectionable definition of it, and quite as inconvenient.

Let us premise that we are not now raising any objection to the above definition drawn from the metaphysics of cause. Our reply is on the same plane of thought as the definition itself. We shall indeed have to appeal to what is involved in the notion of cause, but are not concerned with any deeper question respecting it. Clifford refers merely to the metaphysical objection to the above definition of force, and Tait expressly declares that it is the only objection. We now accept cause in its ordinary sense, but submit that the cause of motion is *impulse* and *not force.*

Let us observe also that we have no concern now with the question whether mechanical or molar force or pressure does or does not rest upon molecular kinetics as its ground. That is an exceedingly interesting and important physical question, but one with which, we submit, pure dynamics has nothing to do.

Before proceeding further we must ask what is the definite scientific meaning of "force?" Of course we do not presume to answer this question from ourselves. Force is simple pressure or tension which can be measured in pounds weight. It is generally agreed that we get our notion of it from the muscular sense of resistance. It is just what we have said, whether existing under statical or kinetical circumstances. When existing under kinetical circumstances it is proportional to the rate of change of the momentum of the free body concerned.

We must now define "impulse," as we shall have to use the word frequently. "Impulse" means, in this paper, the correlate and numerical equivalent of momentum. It is the quantity signified by ft in the equation $ft =$ momentum, or by $\int fdt$ in $\int fdt =$ momentum. This name is thus applied by Clerk Maxwell and others. Intrinsically it is an excellent name for the thing intended; but it has this objection, that it is generally used, as by Newton, with reference to a sudden, intense, and short-lasting action;* whereas no such meaning is now intended. The force concerned may be as small and the time concerned as prolonged as we please.

The following are either instances of the inconvenience arising from defining force as the cause of motion, or else illustrations of the form of conception which has given rise to that definition.

(1.) This definition is inconsistent with the fundamental equation of motion, viz.: momentum $= \int fdt$, from which we have $f = \frac{d.\,mom}{dt}$. Force then is, or is proportional to, the time-rate of increase of momentum, and therefore cannot be called the cause of the momentum. To call it so is analogous to saying that the death-rate was the cause of the aggregate of deaths in a given city in a given year, or that density is the cause of mass.

* We use "action" here and elsewhere in a free non-technical sense, as is often done by dynamicists.

This may be seen otherwise, by comparing with this equation that of the area A, of a plane curve, viz.: $A = \int ydx$, which is precisely analogous as to its form, and the abstract relations of its constituents. Now, no matter how we interpret the symbols in this latter equation, we cannot say that the y therein is the cause of the area. If y and x be regarded as actual co-ordinates, or right lines, and A as the actual area, y will certainly describe the area, if x increases continuously, carrying y at its end all the while; but y will be utterly inefficacious otherwise. It is importantly *concerned* in the description of the area, but that is all. If the equation be interpreted as purely numerical, it is equally impossible to regard y as being in any true sense the cause of A.

Otherwise thus:—From the very idea of (efficient) cause, it must be regarded as proportional to its effect, if this admit of quantity, "*causa æquat effectum.*" Consequently, if the quantitative effect be increasing, the cause must be conceived of as expending itself at the very rate at which the effect increases. Now, the dynamical *affair* which is expended proportionally with the production of the motion, or momentum, is the *impulse* and *not the force* concerned. (The force is not expended at all, as we shall see in the next section.)

(2.) It is the notion that force is the cause of motion which gives rise to the expression, "expenditure of force," so frequently used by dynamicists and physicists. We are told by the highest and latest authority that "force is wholly expended in the *Action* it produces." But if we reflect upon what we mean by force, as simple pressure or tension, we shall find that it is not capable of being expended; for it cannot be thought of as having *quantity,* though it has *amount,* which may be diminished. Again, suppose that a given statical pressure has been exerted by a spring for ten minutes, at the end of that period it is precisely the same as it was at the beginning. It has not been expended in any proper sense of that word. This is equally true whether elastic force depend upon molecular kinetics or not; and it would be true even if there were expenditure of molecular ability, in order to keep up that force, which, it would seem, no one contemplates.

Similarly with the force or pressure concerned in the production of motion or momentum. Suppose it to be a constant force

applied by a spring which keeps up with the body in its accele-tion, it is, as in the statical case, quite unaltered during the period of the action—it has not been in any degree expended. The force might diminish during the action; but this would be because of other circumstances than expenditure. It might even diminish at the very rate at which the momentum increases; but this would be solely because, from the nature of the conditions, it is always proportional to ε^{-t}.

Otherwise thus—The same persons who speak of the "expenditure" of force tell us that force is the rate of change of momentum. But surely a rate cannot be expended. It may be diminished, it may sink to zero, but not by expenditure. Even though we decline to assert that force *is* the rate mentioned, and cautiously restrict ourselves to saying that it is proportional to that rate, this argument still applies. Returning to the equation of area, we shall see that it is utterly impossible to regard y (which corresponds to f) as having been expended when we have reached the farthest point on the axis of x consistent with the conditions given. This is so even if y there becomes 0, but y may just as well be there at its maximum; that which really has been expended is the whole length along the axis of x, the independent variable (which corresponds to t), allowed us by the conditions.

The expressions which we are now deprecating when applied to force are quite easily avoidable. There are others connected with the idea that force is the cause of motion which are, in reality, equally incorrect; but it must be acknowledged that it would be almost impossible to avoid them without the appearance of pedantry, and, in some cases, without very inconvenient circumlocution also. Force is constantly spoken of as "acting," even when statical pressure is meant; but that which is incapable of expending itself cannot *act* in the true sense of the word, even when concerned in action. Force only exists, or obtains; it is a circumstance, not an agent; it is essentially un-related with time, though it can be brought into connexion therewith; it may be a necessary condition, or an unavoidable accompaniment, of the action which does take place; but that is all. There are other expressions, such as "attractive force," "repulsive force," &c., which it were hard to call incorrect; they are rather elliptical expressions, which it would be excessively inconvenient to give

up; but it is well to be reminded of their real character, though we must continue to use them.

(3.) To say that force is the cause of motion obscures the distinction between force and impulse by making a very prominent statement respecting force which is applicable only to impulse. In some cases it would seem, perhaps, more correct to say that the effect of this definition is to make "force" ambiguous, by giving it two meanings, viz.:—force and impulse. Not long ago "force" (or its equivalents in other languages) was used very generally to mean energy, as well as force. *This* vagueness has now nearly ceased, in this country at least, partly no doubt in consequence of Tait's trenchant remonstrances against it; but the other still obtains to a greater extent than we are conscious of.

The distinguished writers of the following statements, in which "force" means impulse, could not possibly be guilty of the inaccuracy of using "force" for energy.

"It requires an equal and opposite application of force to set a body in motion and to bring it again to rest."

"Forces proper, or (their equivalents) quantities of momentum."

"Change of motion is proportional to the impressed force." ("Change" meaning, as the following context shows, *amount* of change. This is a translation from Newton accepted by the authors.)

What we are now calling by Maxwell's name, "Impulse," requires to have its own proper designation quite as much as energy; impulse and force are fully as disparate as energy and force, and, if possible, even more so than surface and length. Force being measurable in pounds, energy is gauged in *foot-pounds*, and similarly impulse in *second-pounds.*

It is frequently said and written that "force never accomplishes any effect, but in some time," that time is an inevitable or essential condition of its acting, which is always implied, and therefore need not be referred to, except when it is necessary to mention the length of it given by the conditions; since what the given force can perform is proportional to the time of its acting. Now in such statements force really means impulse; it will be seen on consideration that there is here a fallacy in "effect," and, as we have already said, an impropriety in "acting," also that there is a latent confusion between force and impulse of unit of time, both of which are represented by f. It might seem that in the equation of kinetics, $ft = mv$, taken by itself, f should be inter-

preted as force producing momentum for unit of time, and t as the mere number of such units, so that when that number is 1, we have $f = mv$. But we must not forget the relation of this equation to that of energy, viz.: $fs = \frac{1}{2}mv^2$. If we give an interpretation of fs corresponding to that just given of ft, we must say that f is here force doing work through unit of space, and that s is the mere number of such units; thus making f to have a totally different signification in the two equations; but f must have the very same meaning in both; since the latter is derived from the former; and as it does not mean force acting through unit of time in the latter, it must not do so in the former. In both cases it is simple pressure or tension, which is not acting, nor proportional to the amount of the action, but only to the intensity of the action.

Connected with this (whether as cause, or effect, or as a collateral illustration of the same tendency) is an occasional ambiguity in the word "acceleration." This usually means now *rate* of change of velocity; but it sometimes has its simpler original meaning, viz.: *amount* of change of velocity. The effect that this will have on the meaning of "force," if joined with it in the same sentence, is obvious.

(4.) We are constantly told that impulse is "force acting through time." We have already animadverted on force "acting"; but we have now to object further to this statement that it declares that impulse *is* force in some continuous change of condition. This statement is analogous to saying that the area of a plane curve *is* the ordinate moving along the axis of x. It comes very near to identifying *totidem verbis* force and impulse.

(5.) As a little step further (*for the learner*) it is said of impulse (and of its equivalent momentum) that it is the "time-integral of force." What is meant by this is, of course, that impulse is $\int f dt$. This elliptical and conveniently brief form of expression is intelligible enough and quite allowable in other matters; but this statement read in the light of the definition of force as the cause of motion, is calculated to mislead the learner. There is actually some little danger of its reacting on the dynamicists themselves as would appear by the fact that some of them, as another step in advance, tell us that the time-integral of force is "what we may call its whole amount during any time," and that another writer calls it "the total force during a finite time."

Persons can say this respecting force who would not dream of saying that the area of a plane curve is the total amount of the ordinates within given limits; which would be a precisely analogous statement.

(There is a quite similar progression as to energy. Energy is said to be "force acting through space," then the "space-integral of force," then the "sum of the tensions.")

(6.) The following way in which the statical pressure of a weight is regarded by one of our foremost dynamicists illustrates very strikingly the tendency of which we are now complaining.

It is conceived that when a weight is lying on a table, the downward gravity of the weight and the upward resistance of the table are each producing in each second of time a certain quantity of momentum. Observe there is no reference in this to molecular kinetics as the ground of molar pressure; indeed none such would be here of any use. This mode of conception would be quite allowable, as a mathematical artifice, if anything were to be gained by having recourse to it. But it is intended to be what may be called an ontological, or at least a dynamical, fact. The objection to it is that it is a departure from the notion of pressure, which is derived independently of phenomena and relations of phenomena belonging essentially to motion; it is arbitrarily adding to the contents of the notion of pressure nearly all that is wanting to make it into impulse. The two momenta cannot coexist in reality, any more than two equal and opposite velocities in the same point, though it is often a very useful and perfectly justifiable artifice to conceive of these doing so.

We cannot leave the present point without some reference to D'Alembert's principle, which is described as reducing kinetics to statics. Of course nothing that we have said really conflicts therewith. We shall merely observe that it is only by a fiction, though an entirely legitimate one, which constitutes a most useful and perfectly valid method, that the "impressed forces," the "effective forces," and the "forces of constraint," can all be regarded as, in modern language, impulses, which are respectively proportional to their own forces proper. It is only the "effective forces" which are really and literally impulses.

(7.) It is said, as in the above quoted definition of force, by many who perhaps would readily agree to what we have just now said, that statical force "tends" to produce motion, and that

it does not actually do so because it is prevented by the resistance. This has been virtually answered already. If force is not the cause of motion it does not tend to produce it, in any real and useful sense of the expression. But a further reply now suggests itself. If we reflect upon our notions of cause and effect we shall see that that which can exist without producing a certain effect cannot be *the* cause of that effect when it is produced, and therefore does not tend to produce it; it may be a factor of the cause or a necessary condition of it; but that is all.

(8.) Another illustration of the tendency of which we are speaking is the very frequent statement that "the" measure of force is the quantity of momentum that it produces in unit of time. Sometimes this is expressed even more strongly, and it is said that this is the "proper" measure of force. But this is *the* measure of impulse. Force, no doubt, *can* be measured kinetically, and it so happens that, for certain practical reasons with which we are not now concerned, the kinetic measure of force is the most preferable. But to say that the kinetic is "the" measure, or the "proper" measure, of force, and that the Gaussian, or kinetic unit is its absolute unit, to the implied ignoring of the static and energetic measures of it, is unduly emphasizing its kinetic relations. It is calculated to make the learner think that f in $fs=\frac{1}{2}mv^2$ is impulse of unit of time. It is similar to declaring arbitrarily that "the" measure of volume is the weight of the quantity of matter of unit density which would fill it. (In many cases, no doubt, this would be practically the best.)

Let us observe, finally, that the "*vis*" in Newton's Laws of Motion which changes, *i.e.* causes, motion is impulse (see the explanation of Law II.; "*gradatim*," &c., excludes force proper, "*additur*," &c., excludes rate, and posits amount, of change of motion); though in the sentence from the Scholium to the Laws brought into light by Thomson and Tait, *Nam si æstimetur*, &c., "*vis*" is force proper.

XXXII.—ON COMETS' TAILS. BY GEO. FRAS. FITZGERALD, M.A., F.T.C.D., &c.

[Read May 5, 1882.]

IN the last edition of Clerk Maxwell's Electricity and Magnetism, page 402, § 793, he calculates that, according to the electro-magnetic theory of light, sunlight should exert on a body that entirely absorbed it, a pressure equivalent to—

$$P = 4{\cdot}22 \times 10^{-5} \text{ dynes per sq. centim.}$$

Now at the distance of the earth the attraction of the sun for a mass m is—

$$f = {\cdot}59 \times m \text{ dynes.}$$

These forces might balance if the absorbing surface were sufficiently large in proportion to the mass, so that if s were the surface—

$$s \times 4{\cdot}22 \times 10^{-5} = {\cdot}59 \times m$$

or

$$m = s \times 7 \times 10^{-5}.$$

Now the mass of a molecule of a gas of density Δ at the ordinary pressure and temperature is—

$$m = \Delta \times 10^{-21}$$

so that –

$$s = 10^{-17} \times 1{\cdot}4 \times \Delta$$

This gives the surface of a molecule of a gas whose density is Δ in order that it should be neither attracted nor repelled by the sun. If this were the case at one distance it would be so at all distances, because both the attraction of the sun and the intensity of the light vary inversely as the square of the distance. To find whether this is possible we must make some assumption as to its shape, and I will assume that the molecule is spherical, which will have as small a surface as possible, and apply it to the case of Hydrogen. In this case assume ν the radius of a molecule. Then evidently—

$$s = \pi\nu^2 = 3{\cdot}1 \times \nu^2 = 1{\cdot}4 \times 10^{-17} \times \Delta$$

$$\therefore \nu^2 = 4{\cdot}4 \times 10^{-18} \times \Delta$$

In the case of Hydrogen—

$$\Delta = 8\cdot 8 \times 10^{-5}$$

$$\therefore \nu^2 = 38\cdot 72 \times 10^{-23}$$

$$\therefore \nu = 2 \times 10^{-11} \text{ nearly,}$$

so that this is still only one tenthousandth part of the mean distance between them, and is considerably less than the size of a molecule as usually estimated. Of course no gas would absorb all the light that falls on it, but from these calculations it seems possible that a light gas, with large molecules, such as some of the complex hydrocarbons that absorbed a considerable proportion of the radiations that fall on them might not only be in equilibrium under the attraction of the sun and the repulsion of its radiations, but might be repelled by the sun with considerable force. It has been lately shown that a repulsive force emanating from the sun would account for comets' tails. The force however must not be like gravitation, proportional to the mass of the body, for some comets have more than one tail, and this requires a different accelleration on some kinds of the cometary matter from that on others. This would be completely accounted for by the hypothesis I have put forward. The repulsion of the sun depends on the surface of the molecule and on its absorbing power for heat, and these are not by any means proportional to its mass.

Note added in Press.—1st August, 1882.

Another method can be founded on calculating the proportion of heat that should be absorbed by the unit volume of a substance in order that it be neither attracted nor repelled by the sun. As before the pressure on a completely absorbing unit volume would be—

$$P = 4\cdot 2 \times 10^{-5},$$

so that if a were the absorbing power the force on it would be—

$$F = 4\cdot 2 \times 10^{-5} \times a.$$

On the other hand the attractive force on a unit volume of density Δ would be—

$$F = \cdot 59 \times \Delta.$$

Hence in order that these might be equal we must have—

$$a = 1{\cdot}1 \times 10^4 \times \Delta.$$

Now in the case of Hydrogen at the usual temperature and pressure—

$$\Delta = 8{\cdot}8 \times 10^{-5}$$

so that—

$$a = {\cdot}96,$$

or it would have to absorb 96 per cent. of the radiations that fell on it. From this it seems almost certain that this repulsion can have hardly any effect on the motion of gases under the action of the sun. As however but little is known of the thickness of the layer of gas that will absorb all the heat that the gas will easily absorb, it may be premature to decide finally upon the question.

XXXIII.—PALÆOZOIC ROCKS OF GALWAY AND ELSEWHERE IN IRELAND, SAID TO BE LAURENTIANS. By G. H. KINAHAN, M.R.I.A., &c. With Plates XXX., XXXI., and XXXII.

[Read, May 15th, 1882.]

It is well known to Irish geologists that Jukes, years ago, suggested that some of the rocks of Donegal might be of Laurentian age; while King, of Galway, made a similar suggestion in reference to the rocks of Bennabeola, or the Twelve Pins* of Connemara. Jukes published this opinion in his geology (1862), to which I refer in the "Geology of Ireland." Subsequently, T. Sterry Hunt, in a paper on metamorphic rocks read before the Royal Geological Society in 1863, stated that many of the Donegal rocks appeared to him to be lithologically identical with those of the American Laurentians; while at the same time he pointed out that other rocks from the same area "cannot be distinguished from those which characterize the altered Palæozoic strata of America," which are later than the Laurentian.

In March, 1881, after the question of the possibility of Laurentian rocks occurring in Ireland was mooted by Dr. Hicks and others, I wrote a paper pointing out all the different tracts of old rocks in Ireland having lithological characters more or less similar to those of the American Laurentians, but at the same time I showed that they were also very similar to the American metamorphosed Huronians. (Lower or Cambro-Silurians.)† Dr. Hicks had previously suggested that my "supposed upper Cambrians," in the county Tyrone, to the eastward of Omagh, might be Laurentians; while still more subsequently Drs. Callaway and Hull published that they had discovered Pre-Cambrians in Wexford, Mayo, and Donegal.

Counties Donegal, Tyrone, and Mayo.

In connexion with the Donegal rocks, I have carefully studied all the statements published, and cannot see that their claim‡ to the title of Laurentians has been satisfactorily proven; on the con-

* Called Twelve Stacks or Pins "by the mariners coming in from the maine" (O'Flaherty, History of Hiar Connaught).

† The MS. of this paper was mislaid, and consequently it did not appear in the "Geological Magazine" until September.

‡ Dr. Hull. Scientific Transactions, Royal Dublin Society, Vol. i., Ser. ii., page 243.

trary, some of the facts put forward would seem to imply that the gneiss is only a portion of the rock-formations of the district, which has been more metamorphosed than the rest.

Dr. Hull declares that he has carefully examined the boundary between the supposed older and younger rocks. He is obliged to have recourse to the supposition that there is not only an unconformability, but even a "double hiatus" between them; but no substantial evidence for an unconformability is given. He acknowledges that there are various lines of fault bounding the more metamorphic rocks; and concealed faults often cause a delusive appearance of unconformability. It is a common occurrence, well known to those who have studied metamorphic regions, that the more altered rocks often lie against the less altered. Rocks of both these classes will be found in places in West Galway, in the area now said to be occupied by Laurentian rocks. Moreover, in the "Geology of Ireland" I have described and mapped some interesting patches of such, more intensely altered rock, near the Ovoca mines, county Wicklow. These are patches of "baked rocks" (paroptetic), but in the same district, at Carrig, a few miles to the northward, may be seen granitoid gneiss bounded by similar lines of breaks; and the published descriptions of the lines of boundaries of the Donegal gneiss would be applicable to many fault boundaries in all metamorphic regions.

In America and Scotland basal conglomerates prove the unconformity between the Laurentians and the newer rocks, but neither in Donegal, nor with the rocks of Tyrone, N.E. of Omagh,* nor in the Ox Mountains, nor in Slieve Gamph, nor in N.W. Mayo, near Belmullet, *have such conglomerates been recorded, although two great hiatuses are supposed to exist between the old and the younger rocks.*

If these rocks, from their lithological characters, are to be classed as Laurentians, why are others of similar characters, and

* These and the overlying unaltered fossiliferous rocks were originally said to belong to the one group: but after I had shown that this was impossible ("*Supposed upper Cambrian rocks in the counties Tyrone and Mayo.*"—*Proc. Royal Irish Academy*, *2nd Ser.*, *Vol. iii. Science, p.* 343), Dr. Hull has suggested, first, that they are the lowest portion of the Cambro-Silurian, that is the Arenig group, and afterwards that they are Laurentians. In either case it is stated that my supposition is probably wrong; although my statement is; they "*are probably equivalents of part of the Arenig group*" *of Wales, put by some geologists among the Cambrians.*" And among these Geologists are Lyell and Ramsay.

very similarly circumstanced, to be differently treated? Such as the rocks in the neighbourhood of Petigo, on the north of Lough Erne, as also the rocks of the small tract in N.E. Mayo, southward of Charlestown, which in Griffith's and Jukes' maps are marked as metamorphic rocks; but which are grouped in Dr. Hull's maps with the overlying unmetamorphosed fossiliferous upper Silurians. In these metamorphic rocks the granitone is very similar to some of the Laurentian rocks.

As the principal object of this paper is to treat of the tracts with which I am more especially acquainted, I will not now dwell further on the rocks of the above areas; especially as the arguments and facts already put forward elsewhere, in favour of their being of Cambrian age, remain unanswered.

County Wexford.

The Wexford rocks mapped by me as Cambrians are divided into two areas by a trough of Carboniferous rocks. In the area to the S.E. of this trough or band, which may be called the *Carnsore district*, the rocks, as a general rule, are more altered than those to the N. and N.W. of the band. No one can positively assert that the rocks at both sides of the band are of the same age; but, on account of the similarity between some of the rocks in the Ballycogley section, and some of those northward of the band, I believe all belong to one group; and those to the northward of the band are evidently Cambrians, as they contain the characteristic fossil, *Oldhamia*. Dr. Callaway, indeed, does not separate the rocks northward and southward of the band; but he would wish to divide those in the *Carnsore district* into groups of distinct ages. The rocks in this area are not well exposed; but by combining the sections on the coast at Crossfarnogue and Kilmore Pier, with those at Ballycogley, near Lady's Island Lake, and that along the east coast, a very fair section across the whole can be constructed; from which we learn that there is a gradual merging from granite, through gneiss, into schist, as the rocks are followed northward from the south coast. Dr. Callaway suggests that there is an unconformability in the Crossfarnogue section; but this is impossible. He also states that the unconformable boundary of the mass of metamorphosed eruptive rocks, including agglomerates, near Greenore, prove that

those rocks are much older than those with which they are associated. This unconformability, however, does not appear to me to be of any importance, as such is there to be expected; because agglomerates usually form protrusions in the rocks with which they are associated;—witness the massive agglomerates in the Carboniferous rocks of Limerick, and elsewhere, and those in the Lower Old Red Sandstone (*Silurian*) of Cork, Kerry, and Roscommon; moreover, in the metamorphic rocks of Galway (*Cambro-Silurian and Cambrian*) there are masses more or less similar to that near Greenore; and to me it would appear absurd to say that the agglomerates in any of these places are more ancient than the associated rocks; as in each case they belong to the rocks with which they are associated.

In connexion with the Co. Wexford it may interest enterprising Laurentianists to suggest to them a new field for inquiry, which is the range of hills adjoining the mearing of the counties of Wicklow and Wexford, and extending from Croaghan Kinshellagh nearly to Kilcavan, as here there are many rocks of Laurentian types.

West Galway.

The rocks in this area I have worked most carefully; and it was not until after this examination was complete, and after I had carefully plotted sections across them, under the surveillance of Dr. Hull, that my opinion as to their age was matured. These sections were exhibited and explained* at the meeting of the British Association in Belfast (1874); and, if these are compared with the sections that have been published of the district, it will appear that the latter, although they are supposed to be taken from my work, are a mistaken misrepresentation of the facts as I have given them. Some of the most important incorrectnesses are, *first*, the rocks of the ophicalcite series are represented as being above the great quartzites of Bennabeola, while, in every case, they are below them; *second*, the rocks now said to be Laurentian—that is, the rocks south of the valley from Clifden to Oughterard—have a general dip southward, or away from the quartzites of Bennabeola. In some places they are inverted and reversed, as pointed out in the *Geological Survey Memoir*, while in other places there may be local northward dips due to the transverse faults; but the main dip is to the south, conformable with that

* By special permission of the Director-General.

of the underlying older quartzites, and not northward, as represented in these sections.*

In the Transactions of this Society, vol. i., pl. xxi., fig. 6, Dr. Hull gives a nearly north and south section across West Galway, in which the supposed Laurentian rocks are separated from the others by the great fault of the Clifden and Oughterard valley. This fault, as I have shown in the Government Survey Memoir, is a downthrow to the south. To meet Dr. Hull's idea, it would have to be a great downthrow to the north of over 5,300 feet. Even if Dr. Hull's general dip were correct, I do not understand how the rocks could get into the position represented as the result of a northern downthrow.

As has already been mentioned, Dr. King, before I examined the country, suggested that the quartzites, ophiolites, &c., of the Bennabeola and neighbouring hill groups were Cambrian or older; while, during the time of my examination, Sir R. I. Murchison, in a paper in the *Geological Magazine*, gave it as his opinion that the rocks of the Bennabeola mountains were of Laurentian age; which opinion he withdrew in a paper in the next number of that journal. During my explorations I searched diligently for an unconformability, or some indications of one, but found none; and my examination of the district, with a due and deliberate consideration of the facts detected, forced me to come to the conclusion that the rocks formed a continuous sequence, the oldest being of Cambrian and the youngest of Cambro-Silurian ages, with between them rocks representing the "Arenig rocks" of Wales, on the passage-beds between the Cambrians and the Cambro-Silurians; and from his preface to the Geological Survey Memoir (Exp. sheets 93, &c.), it appears that Professor A. C. Ramsay came to a somewhat similar conclusion during a short run through the country in the company of Dr. Hull.

As with the Tyrone rocks, so with these—the changes in opinion as to their supposed age have been sudden and unexplainable. In

* The maps and sections were carefully explained to Sir Richard Griffith, and left with him to examine, who, when returning them to me, expressed in a letter that he considered I had unravelled the geology of the district; and I find by a subsequent letter, dated Hendersyde Park, Kelso, N.B., Nov. 19, 1872, that Griffith was of the opinion that the rocks of the Forth mountains, Co. Wexford, the Cambrians of Wicklow, the rocks of the Twelve Pins, Connemara, and the rocks of Donegal, probably all belonged to one and the same geological period.

1874, when my work was finished, Dr. Hull appeared to agree with my opinions; but shortly afterwards when the memoir was published he insisted on saying that the result of my work was to prove the Lower Silurian age of all; yet afterwards, when he published his section, he suggested that some of them were probably Cambrians; while now he has again changed his mind, and declares that he "can have no hesitation in referring them" to the Laurentians.

In the Geological Survey Memoir, and also at page 21 of the "Geology of Ireland," I have shown that these Connemara rocks lie on an anticlinal curve, and that they range both northward and southward, in regular and similar sequences, from the lowest exposed strata in the western portion of the Bennabeola hills; as represented in the Diagram, Plate XXX.

General Section of the Connemara Anticlinal.

	North Side.	*South Side.*
	Cambro-silurian.	
B 12.	*Croagh Patrick beds,* with inliers of serpentine, steatite, limestone, and hornblende-rock.	*Lettermullen beds,* with inliers of limestone, hornblende-rock, &c. (submetamorphic.)
B 11.	*Doolough beds,* fossiliferous in part. (Llandeilo), submetamorphic in part.	*Hornblendite and talcite series.*
	Arenig.	
B 10.	*Great micalite series,* having in it, above, inliers of hornblende-rock, ophite, steatite, &c.	*Great micalite series,* having in it above, inliers of hornblende-rock, ophite, steatite, &c.
B 9.	*Lettermore quartzite series.*	*Small quartzite series.*
	Cambrian.	
B 8.	*Kylemore series,* containing many limestones.	*Ballynahinch series,* containing many limestones.
B 7.	*Middle micalite series.*	*Middle micalite series.*
B 6.	*Great quartzite series.*	*Great quartzite series.*
B 5.	*Small micalite series.*	*Small micalite series.*
B 4.	*Ophiolite and dolomite series.*	*Ophiolite and dolomite series.*
B 3.	*Quartzitic micalite series.*	*Quartzitic micalite series.*
B 2.	*Streamstown limestone series.*	*Streamstown limestone series.*
B 1.	*Lower micalite series.*	*Lower micalite series.*

From the diagram and this general section, it will be seen that to the north and south of the curve the succession of the groups is similar, although the groups differ in thickness; while the sections across Bennabeola and the Corcogemore hills (Plates XXXI. and XXXII.) explain the present conditions of the groups; all the strata being more or less moved from their normal positions by the numerous faults that traverse the area in various directions.

From the section across Bennabeola, we learn that the great nearly E. and W. fault of the Clifden and Oughterard valley brings down the rocks of the *Middle micalite series* (B 7) against those of the *Quartzitic micalite series* (B 3), thus cutting out the intermediate groups, besides inverting the dip of the strata to the south of the fault. Here the order of the rocks is very much confused by the displacements due to this and other faults; the rocks of the *Great quartzite* and associated series being concealed in the country to the south of its line; but if we go further eastward to Lissoughter and to the Corcogemore hills, we find the *Ophiolite, Small micalite* and *Great quartzite series* (B 4, B 5, and B 6) lying on the ridge of the anticlinal curve, and dipping both to the northward and southward under the younger groups. The section to the southward is very complete, as only the *Small quartzite series* (B 9) and part of the *Ballynahinch series* (B 8) are concealed by the *Clifden and Oughterard fault,* while all the rocks dip regularly southward.

Elsewhere, as in the Geological Survey Memoir and the "Geology of Ireland," I have divided the metamorphic rocks into the *Gneiss series,* the *Schist series,* and the *Submetamorphic series.* If the county is traversed from Clifden southward to Ballyconneely, the rocks are found to belong to the "Schist series;" but the metamorphism probably decreases southward; because to the south-east and south, of a portion of the excessively metamorphosed rocks, in Lettermullen and Gorumna, the rocks of the *Lettermullen series* (B 12) are only submetamorphic.

If from the schists between the Clifden valley and Ballyconneely, we proceed eastward along their strike, they are found to graduate through gneiss into granite; this, however, does not take place suddenly, as before the main mass of the metamorphic

granite and granitoid gneiss is reached, outlying patches of these granites and gneiss occur in the country southward of Glendalough and Recess.

It will be also found that the further we proceed eastward, the more of the rocks of the older groups are absorbed into the granite and gneiss; so that in the country south and south-east of Oughterard, the intense metamorphism has also affected the rocks from those of series B 11 down to those of the Ballynahinch series (B 8). Going eastward from the Atlantic to the south portion of Lough Corrib, the graduation is along the strike of the strata; but it is transverse to it if we go south from Oughterard to Galway Bay.*

Let us now go from Bennabeola northward across the north series of the anticlinal, and we find that the rocks graduate from schists, through submetamorphic rocks, into unaltered fossiliferous rocks (*Doolough beds*), (B 11), at Rossroe, Mweelrea, and Toormakeady, the fossils being of Llandeilo type; while if the fossiliferous rocks of Mweelrea are followed eastward, they are found to have graduated into schists in the country between Doolough and Lough Mask.

In Mr. Mitchell Henry's hills between the Kylemore and Culfin valleys the hornblende-rock, ophites, &c., the upper members of the *Great micalite series* (B 10) are conspicuously developed· This is a very interesting district, as some of the rocks in it, which are undeniably above the quartzites of Bennabeola (B 6), are lithologically more allied to the Donegal rocks than any others in West Galway; and it appears to me if the similar rocks, to the south, in the *Great micalite series*, are to be classed as Laurentian that these also must be similarly classed; which would be absurd.

Furthermore, beginning to the N.W. at Ballinakill and going eastward and south-eastward along, the rocks of the Kylemore Limestone series (B 8), past Kylemore and the Maum Turk

* Mr. E. T. Hardman has called my attention to conglomeritic rocks that contain blocks and pieces of grabbro, which he found in the supposed Laurentians of Sligo and Leitrim; and he suggests that these must be pieces of rocks belonging to an older group than that in which they are now found. I would also point out, as I have mentioned in the Geological Survey Memoirs and elsewhere, that there are very similar conglomeritic rocks in the co. Galway in the rocks now said to be Laurentians. These Galway conglomeritic rocks are in the *Hornblendite and talcite series* (B 11), while the contained pieces are similar to rocks in the *Great micalite series* (B 10) which was one of my reasons for supposing the latter rocks to be older than the former.

hills to Oughterard, and thence westward to Clifden, we find the same series of strata around three sides of the *Great quartzite* (*series* B 6) of the Connemara hills; while outside these rocks, except to the south and south-east of Oughterard, where they are changed into gneiss or granite, we find the rocks of the *Great micalite* (B 10) and the *Hornblendite* (B 11) *series*; which appears to me also strong evidence against the rocks south of the Clifden and Oughterard valley being of Laurentian age.

In conclusion, I would specially point out that I have never asserted that there are no Laurentian rocks in Donegal; but I do assert *that conclusive proofs of their existence therein have still to be produced.* Years ago Dr. Haughton classed the granitic rocks of Donegal and Galway together, and now Dr. Hull states he has no hesitation in referring both to the same geological time, while Dr. Sterry Hunt has stated that certain altered Palæozoic rocks, later than Laurentian, cannot be distinguished from some of the Donegal rocks. If therefore these Donegal rocks are lithologically similar to those of Galway and to the Cambro-Silurians of America, one of the arguments in favour of their being Laurentians falls to the ground.

Of the area near Belmullett, N.W. Mayo, I have only a limited knowledge, having been there only for a few days; but on seeing the rocks I was at once struck with the great difference between them and those with which they were associated, and, as I have already mentioned in a previous communication to the Society, with their similarity in many peculiarities to the granitic rocks of Carnsore, county Wexford; for which reason I suggested that they were probably of Cambrian age.* In regard to the other areas of supposed Laurentians, I believe that elsewhere I have given better reasons for supposing them to be of Cambrian age† than any which have since been put forward in support of their being Laurentians; it is therefore unnecessary to repeat them.

I have observed that some, at least, of the Laurentianists, when it suits them, lay great stress on the lithological characters of rock at great distances from one another; while, if these characters do not support their theory, they get rid of the difficulty by saying that the change is not greater than what

* Scientific Proceedings of the Royal Dublin Society. *Antea* page 143.

† "Supposed Upper Cambrian rocks." Royal Irish Academy Proceedings, 2nd Series, Vol. iii. (Science), page 343.

might be expected on account of the distance between the places. As elsewhere, so I would now again point out that the Laurentianists pin their faith too much on lithological characters; while they nearly altogether neglect petrological or stratigraphical evidence; and it would appear to me that if they go on as they have began, we shall have, before long, every metamorphic region, no matter what the age of its strata, dotted over with their Laurentian rocks.

Note in Press.

In a paper on the "Geological age of the Taconic system," read before the Geological Society of London, Professor J. D. Dana, in opposition to the view that the geological age of strata can be inferred from their mineral characters, pointed out what remarkably different rocks have been produced by the metamorphism, in different degrees, of the strata of Taconic range.—*Geol. Mag., New Series, Decade* ii., *Vol.* ix., *page* 282 (June, 1882).

Description of Plates.

Plate XXX.—Diagrammatic section of the rocks of the Bennabeola mountains, showing the relations that originally existed between the different series of strata that lie on the south and north slopes of the great west and east anticlinal curve.

Plate XXXI.—South and north section across the Bennabeola mountains, showing the present position of the strata on the south and north of the great W. and E. anticlinal due to their displacement by numerous faults and breaks. The main west and east fault occurs in the Clifden valley. It is a downthrow to the south, and here brings down the younger rocks of the *Middle micalite series* (B 7) against the much older rocks of the *Quartzitic micalite series* (B 3).

Plate XXXII.—South and north section across the Corcogemore hills, showing the present position of the strata on the south and north of the great W. and E. anticlinal due to their displacement by numerous faults. The main west and east fault occurs in the valley at the foot of the south slopes of Corcogemore. Here it has not as great a south downthrow as farther west. It brings down the rocks of the *Great micalite series* (B 10) against those of the *Ballynahinch series* (B 8).

XXXIV.—ON THE METAMORPHIC ROCKS OF COS. SLIGO AND LEITRIM, AND THE ENCLOSED MINERALS WITH ANALYSIS OF SERPENTINE, &c. BY EDWARD T. HARDMAN, F.C.S., WITH MICROSCOPICAL NOTES ON THE SERPENTINE. BY PROFESSOR HULL, LL.D., F.R.S. PLATE 33.

[Read June 19th, 1882.]

PART I.

The portion of the metamorphic rocks referred to in this paper includes the N.E. extension of the Ox Mountains, from Colooney to the north of Manorhamilton, a considerable part of which forms the southern shore of Lough Gill.

Besides this principal mass there is an inlying portion protruding through the carboniferous rocks of Rosses Point to the north-west of the principal mountain line and 9 or 10 miles distant from it. The general characters of both agree however in all essential respects.

1. *Ox Mountain Range.*—These rocks form a ridge some 3 to 4 miles wide, showing a series of irregular peaks semi-rounded by glaciation. The principal heights are about 900 feet, although Benbo Mountain rises to an elevation of 1,365 feet. The other chief elevations are Benbo Hill 849, Rockwood (or Slish Mountain) 967, and Slieve Deane 900. South of Lough Gill, Union Wood 440; and Carrownageeragh to the west of Colooney. The last being 602 feet.

The north-west boundary of these rocks is very precipitous in places, especially in the district between Ballisodare and Slishwood, where there is a cliff boundary about 100 feet high. This marks a line of fault which has been traced from near Ballisodare to Saddle Hill, county Leitrim, a distance of over 20 miles.

On the south the rocks, although rugged, are not very precipitous, and while it is probable that a fault occurs on this side also, it is not so apparent as on the other side of the range, in both cases bringing down the carboniferous rocks, on the north side (the downthrow being the greatest), the Upper Carboniferous

Limestone, and on the south the Lower Limestone. See section, Figure 1 (on page opposite).

General Character of the Rocks.—In this district there is not always to be drawn a hard and fast line between the different varieties of the few metamorphic rocks which occur in it. These consist indeed of but four classes, viz.: granitoid gneiss, gneiss proper, mica schist, and quartzite. But in few cases is it possible to determine a boundary between any two of them. Thus the first may be seen to pass into the second, and so on.

A good example of this is to be seen in the section west of Slieve Deane, where in the space of some 400 yards, there are numerous transitions of gneiss, schist, and quartzite into each other, without any apparent rule or order in the process, all apparently changing indifferently one into the other.

On the whole the gneiss largely predominates, the quartzites come next, and the mica schist last of all.

Of these the gneiss is the most interesting, from a mineralogical point of view; containing, as it does, a great variety of large crystals of quartz, biotite, muscovite, tourmaline, felspar (both red and white orthoclase), hornblende, and olivine, and very often garnets, but in minute crystals.

It is also remarkable for a curious band of conglomerate which occurs north and south of Ballydawley Lake, near Union Wood. This rock is a coarse granitoid gneiss, containing lenticular blocks and rounded pebbles of diorite or hornblendic rock weathering out on the surface.

South of the lake, and nearly a mile from the first exposure, the same conglomerate appears, although shifted to the east by a fault. Here some of the boulders are 2 feet long, and 8 to 10 inches wide. The whole visible thickness of this bed, or series of beds is about 200 feet, and it is an important find in one way, namely, that whether we consider the diorite pebbles to be altered or not from the parent rock, their presence in the gneissose beds proves the existence of an older rock prior to even the formation of those beds.

Serpentines.—Three well-marked bands of serpentine occur in these rocks. The chief one appears at Slishwood, and occupies the valley running nearly south from Bunowen Bay, Lough Gill, for nearly two miles, and has an average width of about 500 feet. It will be fully described further on. Its chief peculiarity is that it is highly magnetic.

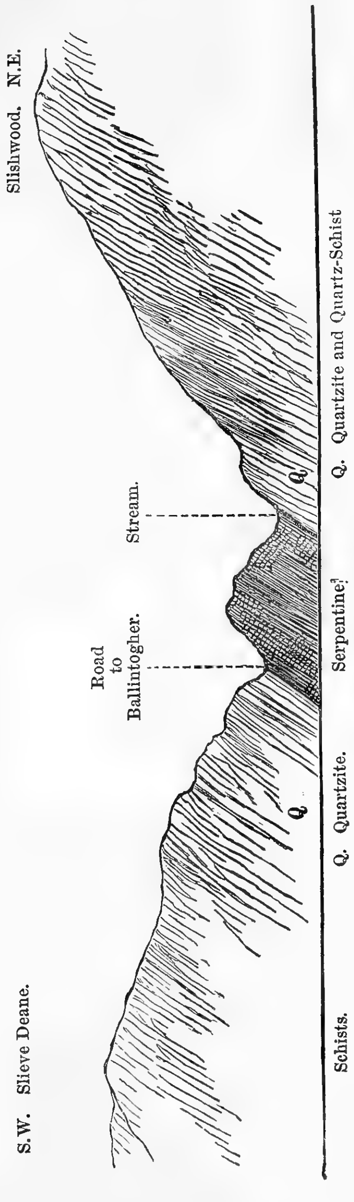

FIG. 1.—Section across Slishwood and part of Slieve Deane, showing position of Serpentine rock.

Next comes a band near Drumahaire (three miles N.E.), trending nearly east and west. It is probably 300 feet thick at least; but its extension along the line of strike is not ascertainable, owing to thick coverings of drift and bog.

Finally, close to Shanavan's Bridge, near Manorhamilton, there is a well-defined band of serpentine, trending nearly N.E. and S.W. It is, however, cut off by two faults, and can only extend about half a mile in each direction. This contains mica and chlorite.

Neither of these last serpentines are perceptibly magnetic, although not generally different in external appearance from the first. They also want the numerous bands of tremolite which distinguish the former.—(See Part III., p. 368.)

Rosses Point Section.—In this region a triangular boss of metamorphic rock occurs, which has not yet been noted on any map, or in any other publication. It is about $2\frac{1}{2}$ miles long, and about a mile at its greatest width. It is difficult to account for its appearance here, within the limestone district, unless we suppose it to have been upheaved by more than one fault. One to the north is sufficiently apparent, but the other junctions are hidden by drift.

The rocks in this district are of a similar character to those of the Ox Mountains, and consist of coarse gneiss, often hornblendic, and mica schist. Quartzites are absent. The gneiss contains in places small garnets.

List of Minerals, and Remarks thereon.

Quartz.—Disseminated throughout; sometimes occurs in large ill-defined crystalline masses.

Felspar.—Chiefly, if not altogether orthoclase, both white and pink; the latter very common; both often in extremely large crystals, as near Colooney, also in the rock north of Ballintogher.

Mica.—Muscovite and biotite are found very usually in the same rock, often in very large crystals. Some specimens (muscovite) obtained near Ballintogher afforded flakes more than $1\frac{1}{2}$ inches in diameter.

Tourmaline is not unfrequently met with in small crystals. Near Colooney a magnificent mass occurs, consisting of large crystals, radiating in a star-like form, about two feet in diameter. The crystals, which have a tapering form, are some-

times nearly one inch in diameter at the base. They are enclosed in milk-white quartz, which retains a perfect cast of the form and striation of the crystal, and must, therefore, have been deposited later. The contrast presents a very beautiful appearance. Associated with these is pink felspar in very large crystals.

Olivine is disseminated in small crystals in many places.

Garnets are found near Rosses Point, and in the coarse gneiss west of Carrigeencor Lake. They are very small.

Copper Minerals.—Chalcopyrite occurs in quartzite near Shanavan's Bridge, in an old copper working.

Azurite.—Very beautiful specimens were obtained at the same locality.

Malachite is found at the same locality associated with the other copper minerals. It also occurs in a decomposed vein in quartzose schist, associated with galena, one mile N.E. of Manorhamilton.

Galena in small quantity in last two localities.

Cobalt.—In the last locality some specimens, apparently containing cobalt, were obtained.

Pyrites.—This is found in small specks throughout. It is associated with the copper minerals at the mine at Shanavan's Bridge.

Geological Age of the Metamorphic Rocks.

On this point we have as yet no definite information. That they are extremely old we cannot but admit. Unfortunately, in the Sligo district the links between the carboniferous and older rocks are wanting, and it is only possible to judge from analogy, and resemblance to other rocks of known age. Accordingly, they have been ascribed to a very early age by most geologists—amongst others, Mr. Kinahan places them in the Cambro-Silurian,* while Professor Hull traces their origin still further back, to the Laurentian system †; and there is indeed no reason to deny that they may even be of that vast age.

The Section will demonstrate the difficulty of determining their age on stratigraphical grounds alone.

* Geology of Ireland, p. 216.

† "On the Laurentian Rocks of Donegal, &c." Scien. Trans. Roy. Dub. Soc. Vol. I., Ser. II., p. 252.

Part II.

The highly Magnetic Nickeliferrous Serpentine, from Slishwood, near Sligo.

This rock is of a rare character, and I believe that up to the present no serpentine containing magnetite in quantity has been recorded as having been noticed in Ireland. So far as I am aware the only instances given of such a rock are those cases mentioned by Bischof, as occurring at the Heidelberg, near Darmstadt; and at the Auschkul Lake.* The description of the first of these resembles in the closest manner that of the Sligo rock, as will be seen hereafter.

The serpentine at Sligo forms a well defined and very regular band amongst the metamorphic rocks on the southern shore of Lough Gill, and extends from Bunowen Bay along by Slishwood, in a south-easterly direction for about a mile and a half, when the Carboniferous Limestone supervenes, and cuts it off. It has a thickness of about 500 feet, being, as observed by Professor Hull, the most extensive and regular band of serpentine in Ireland. The section on page 359 will explain the manner in which it occurs.

Physical Characteristics.—The rock is apparently an ordinary common serpentine—dark coloured, compact, and somewhat hard. The bedding is very distinct, and along the planes of bedding, well defined bands may be seen, which, at first sight, appear to be bands of grit, but on closer inspection prove to be bands of a hydrous silicate in all essential points resembling serpentine, but containing a larger quantity of water. In all parts of the rock magnetite occurs, but chiefly on the western side of the band. To the eastwards the rock is more homogeneous, and it was when examining the tiny black particles which appear in this part of the rock, that I became aware of the magnetic character of it. In the most compact specimen of this rock minute grains of black matter will be seen, and on powdering a portion, and running a magnet through it, a quantity of magnetite can be extracted. Tracing the rock to the westwards, this mineral becomes more and more abundant, and close to the western boundary occurs in very large quantity indeed, and portions of the rock possess all the characters of natural magnets. They attract and repel the magnetic needle, and have distinct polarity.

* See chapter on Serpentine. Chem. Geol., Bischof.

Some specimens now exhibited have this property in a very marked way.

It is towards this side also that the fibrous mineral most predominates, and this mineral also contains a very large quantity of the magnetite, which is disposed in lines along the planes of lamination, and, as in the case of the other portions of the rock, *almost parallel to the magnetic meridian.*

Polarity of the Rock.—As to the precise direction of the poles of the rock, I am not quite confident, but I believe them to lie for the most part very nearly north and south—the N. pole of course to north. There is a difficulty in obtaining specimens out of the mass, in such a way as certainly to identify their original position, the rock being very splintery; but the majority of my observations leads me to the above opinion. In at least one case, however, the poles were inclined with the dip of the rock. The north pole being lowest, and towards the west, the south being uppermost.

Effects on Surveying Instruments.—As may be supposed, the rock has a very decided effect on the magnetic needle, and I made some few experiments to test the amount of this. Taking a point about the centre of the rock, I made a traverse on each side for about 300 yards, and I found a difference of 5° in the readings of the compass between the points on each side. It was, however, very difficult to be certain as to the North point, and I did not altogether rely on these observations. In order to make sure, the following plan was adopted :—A tree, nearly due west of one on the rock was chosen, and about 1000 feet distant. The observation with the prismatic compass was as follows :—

Reading from distant tree to that on rock -	90° 30′
,, ,, tree on rock to above - -	264° 00′
The correct reading should be - - -	269° 30′
	264° 00′
Therefore disturbance of needle - =	5° 30 to E
The direction of a portion of the road was taken (close to rock) - - =	177° 00
Direction as obtained from 6-inch map =	175° 00
Deflection - - -	2° 00.

The prismatic compass I used was the reverse of delicate, and not much affected by small portions of the most magnetic specimens.

I should mention that this effect on the magnet would appear to have been observed before, for when I was examining the rock an intelligent old countryman came up and spoke thus—I give his own words, as they are brief and pithy: "That's a mighty quare rock, sir. They do say that it never could be surveyed by mortal man. Them that tried it always found their instruments went wrong, and they could make no hand of it at all, at all."

Chemical Composition.—This is nearly that of most rock serpentines, except that it is highly aluminous even when it is perfectly compact and has no visible traces of tremolite or asbestus, in which alumina might be supposed most likely to occur. Indeed an analysis is not required to prove this point as the compact rock when breathed upon gives the peculiar earthy odour of aluminous rocks; but the chief points worthy of remark about the rock are the presence of magnetite and of nickel. As to the latter it has not often been found in serpentine. There are a few instances mentioned by Dana. It has been recorded as occurring in the Black Serpentine of the Lizard by Bonney and Huddleston, and I myself have noticed it in that of Croagh Patrick, county Mayo, a rock which closely resembles the Sligo one. It very likely takes the place of some of the magnesium. Stromeyer has obtained from 0·22 to 0·45 per cent. Ni O in Serpentine of Roraas, Tundal, and Saxony; Lynchnell and Sterry Hunt 2·24 per cent., in the serpentine of some parts of America, of Cornwall, of Banffshire, of the Vosges, France.

I have not had time to make a complete series of analysis of this very interesting rock, but the following will give a fair idea of its general character.

ANALYSIS I.

Compact Serpentine. No Magnetite apparent on casual Observation.

SiO_2,	38·13
Al_2O_3,	5·5
Fe_2O_3,	1·30
FeO,	6·00
MnO,	0·95
NiO,	1·25
CaO,	1·00
MgO,	30·32
Water,	12·80
Magnetite Fe_3O_4,	4·0
	99·75

ANALYSIS II.

Containing much Magnetite in Bands.

$Si\,O_2$,	34·06
$Al_2\,O_3$,	6·20
[$Fe_2\,O_3$, *	0·35] ?(doubtful.)
$Fe\,O$,	2·00
$Ca\,O$,	0·85
$Mg\,O$,	31·69
Magnetite,	12·39
Water,	12·46
	99·65

ANALYSIS III.

Another portion of same Specimen.

This gave magnetite 14·35 per cent., but does not materially affect a prismatic compass. It, however, strongly affects a delicate needle.

The de-magnetised portion had the following composition:—

$Si\,O_2$,	39·20
$Al_2\,O_3$, $Fe_2\,O_3$, $Fe\,O$, $Mn\,O$,	11·80
$Ni\,O$,	1·00
$Ca\,O$,	1·00
$Mg\,O$,†	34·48
Water,	13·25
	100·73

NOTE.—The general relation of the silica magnesia and water in this analysis closely resembles that given by Dr. Haughton of the red serpentine of Cornwall. (Phil. Mag., vol. 10, p. 253, and Jukes and Gerkin, p. 142.

I have not estimated the proportion of peroxide of iron, or protoxide of iron and manganese in this specimen. But I may mention that the amount of peroxide is very small, and the greater bulk of the united weight is due to the alumina. It contains 3·75 per cent. of protoxide of iron.

Besides the above I have made several partial analysis of other portions of the rock, but they possess no particular interest except that they show the rock to be throughout of very similar composition, invariably containing alumina and magnetite, with nickel sometimes reaching up to 2·5 per cent.

* In this analysis there is some uncertainty as to the presence of $Fe_2\,O_3$.

† Other specimens of the rock gave 35·00 and 36·45 per cent., magnesium oxide.

It is of course not a normal serpentine insomuch as the proportions are not those of the *mineral,* but in every respect answers fairly to the character of *serpentine rock.* At any rate the term aluminous magnetitic serpentine would be a correct name for it.*

In no case have I obtained a specimen of it *without* magnetite, even the compact specimens contain a little of this, and it occurs in all quantities from 2 per cent. up to 15 per cent. nearly. I have not tested specimens containing less or more, but, I have no doubt they may exist.

If the rock is finely powdered and a magnet passed through it the magnetite forms a brush on the poles; a quantity of it can be taken out thus.

I applied this method for the determination of the per-centage, but I find that Bischof, who has a very aggravating way of anticipating geological chemists, used the same method for the extraction of the magnetite from the serpentine of the Heidelberg. He mentions that as much as 13·6 per cent. was extracted in this way, but that the actual proportion must have been smaller as it would be difficult to eliminate it completely from the rock.

The Sligo rock therefore contains the highest recorded percentage.

In order to be certain that the magnetite was entirely eliminated I subjected the powder to frequent levigation and elutriation, sifting frequently with the magnet, so that I do not believe that 0·10 per cent. of rock remained attached to the mineral when finally weighed.

In conclusion I would briefly remark on the bearing of the presence of this mineral on the origin of this serpentine rock.

I need hardly refer to the fact that serpentine is never found unassociated with metamorphic or igneous rocks. Yet there are some who hold that serpentine may be deposited amongst sedimentary rocks as a wholly aqueous deposit. It will be in memory of those present that Dr. Sterry Hunt in a very able paper read at the last Dublin meeting of the British Association strongly upheld this view.

Now the Sligo serpentine would at first sight appear to agree with this view. It is most clearly a stratified rock, well and very regularly bedded, and perfectly well defined with regard to the

* It is possible indeed that the rock should be called eklogite serpentine if it could be a product of alteration of augitic rocks. This however is improbable.

quartzose rocks on each side. There is no merging of one into the other.

But, on the other hand, how can we account for the magnetite? Supposing we admitted the sedimentary character of the rock. I believe there is no case on record of magnetite being found in rocks other than those which have been metamorphosed, or which are of known igneous origin, and in which it is notably of common occurrence. It is also easily produced by the chemist under conditions of intense heat; but no one has yet succeeded in obtaining it from chemical decomposition in the cold. It may, therefore, be taken for granted that at the time the magnetite was developed in the serpentine that rock must have been subjected to a very intense heat—doubtless a moist heat under great pressure. The rock must, therefore, have been altered since its deposition, and therefore could not have been—what it is now—serpentine originally.

The present case can be easily accounted for by the alteration of ordinary magnesian limestone and shales. This great band of serpentine was perhaps originally a bed of magnesian limestone intercalated between shales and sandstone rocks. Carbonate of lime was gradually eliminated, and replaced by silicate of alumina and magnesium from the accompanying shales, and the oxides of iron under the influence of intense heat and super-heated steam were in part converted into magnetite.

This is partially confirmed in the present instance by the fact that at the basal junction of the rock with the quartzite the serpentine merges into what has all the appearance of altered carboniferous limestone shale.

The probability of such a conversion is, of course, beyond all question. Serpentine is of common occurrence amongst altered limestone, as is mentioned by Bischof and others; and I have myself noticed the actual passage of a magnesian limestone into serpentine near Tramore, county Waterford, where the silurian rocks are greatly invaded by igneous and trap rocks.

Chrysolite and Tremolite, or Asbestus.—I should mention that the Sligo serpentine contains numerous bands of a fibrous mineral which answers to many of the characteristics of chrysolite, but that it contains a very large per-centage of water—as much as 17 per cent., and encloses quantities of magnetite. There are also abundant bands of a mineral which closely resembles tremo-

lite in some cases, or asbestus in others. Besides these there is in joints and fissures abundance of a green mineral whose composition approaches that of true serpentine.*

Part III.

Microscopical Notes on the Appearances of the Serpentine, with Asbestiform Tremolite, from Sligo.

Four specimens of this remarkable material were sent by Mr. Hardman to me for examination, with the following results :—

No. 1. Dense dark-green serpentine, with a narrow band of nearly white fibrous, silky tremolite.†

Microscope.—A thin section transverse to the band of tremolite is well seen with an one-inch objective. The serpentinous mass appears as a light yellowish-green amorphous material, with reticulated or net-like divisions, through which are dispersed formless groups of magnetite grains (Plate XXXIII., Fig. 2). The tremolite appears as a band traversing the mass, with fibrous structure, the hair-like prisms being perpendicular to the walls (Plate XXXIII., Fig. 4). It is divided into two portions by a central band of amorphous colourless matter, and it would appear as if the tremolite had crystalised out from the opposite walls of the fissure on either side, leaving a partially unfilled space in the centre, as in the case of some mineral veins. A few translucent spaces occur amongst the mass of the serpentine filled with a colourless material with a wavy fibrous structure, which probably consists also of tremolite.

Polariscope.—With this the effect is striking. With crossed nicols the serpentine presents a spangled field of rich saphire or indigo blue, of varying depths, and broken up into individual grains of irregular form. With parallel nicols the same mineral has a slightly yellowish tint. With this vivid polarization it may be inferred that the mass is in a molecularly crystalline condition.

* Analysis IV.—Green mineral, like chlorite, but with composition of serpentine—

SiO_2	FeO	Al_2O_3	Fe_2O_3	MgO	Water.	Total.
42·40	2·107	4·80	2·63	32·695	14·69	99·322.

† In the following description I have called the fibrous mineral of these sections "tremolite," in deference to Mr. Hardman's determination; but it does not seem to answer very well in its optical properties to the mineral of this name as described by Rosenbusch. (See *Mickros. Physiographie*, s. 307).

On the other hand, the tremolite with crossed nicols exhibited a deep blue tint, shading off into purple, and finally into golden yellow, according to the varying thickness of the section. With parallel nicols the colours were sulphur yellow, passing into light blue; the fibrous structure is very distinct.

No. 2. Rock formed of alternating dark-green bands of serpentine, and nearly black material.

Microscope.—The appearance is very peculiar. The field shows layers of light greenish-yellow serpentine, with net-like structure, similar to that in the former specimen, but alternating with black bands of magnetite bounded by jagged edges (Plate XXXIII., Fig. 3). These bands are not continuous, but broken, irregular, and variable in breadth, sometimes represented by mere specks. There is also a large irregular mass of magnetite grains enclosed in the serpentine in one part of the field (Plate XXXIII., Fig. 1).

Sometimes along the edges of the bands the magnetite seems to be intimately associated with tremolite, which also occurs in thin bands, being parallel to, or alternating with, the long fibrous prisms. This is shown with a high power (one-fifth objective), where, in one instance, the replacement of the tremolite fibres by little black rods of magnetite dust is very clearly shown. The proportion of magnetite in this specimen is unusually large.

Polariscope.—With polarized light this section presents a very beautiful appearance, owing to the surface being bespangled with varying depths of blue, brought out with crossed nicols. The effects are similar to those described in the case of specimen No. 1, and need not be repeated.

No. 3. Dark-green dense serpentine rock, traversed by approximately parallel bands of light-green silky tremolite (?)

Microscope.—In this instance the light yellowish-green serpentine, and colourless tremolite with fibrous structure, are intimately mixed throughout. The tremolite occurs in irregular —nearly parallel—bands, and the hair-like prisms are arranged perpendicular to the walls of the inside bands; and, as the section has been cut transversely to these bands, the hair-like prisms cross the field from right to left. The serpentine has a reticulated structure.

Polariscope.—With crossed nicols the alternating bands of tremolite (?) and serpentine are clearly defined; the former showing the fibrous structure, and colours of yellow passing into purple; the latter, varying shades of indigo blue.

No. 4. Banded dark and light sap-green rock, with small flakes of mica in the folia.

Microscope.—Surface showing net-like spaces of light-yellow serpentine, mixed with clear colourless spaces, through which are distributed black strings of magnetite dust, sometimes intruding amongst the narrow meshes of the net-work, at other times forming long, slightly-bent bands, with jagged and branching sides. Tremolite is absent from this specimen.

With a high power (one-fifth objective and No. 2 eye-piece) the strings are seen to consist of magnetite dust, or very minute grains, which have apparently been extruded from the clear or coloured spaces during the process of metamorphism, and are now diffused through the minute cracks, and fissures, and joinings of the individual grains of serpentinous matter.

Polariscope.—The polarization in this case differs from that of the former specimens. With crossed nicols the serpentinous mineral often shows a wavy-banded structure of varying shades of indigo blue, like some varieties of agate. Throughout this mass are strings and branching veins of a mineral, evidently of newer formation, and polarizing with an opalescent play of colours where the prisms are crossed. I am uncertain as to its nature, but it may possibly be quartz.

SCIENTIFIC PUBLICATIONS OF THE ROYAL DUBLIN SOCIETY.

TRANSACTIONS: *Quarto, in parts, stitched.*

Vol. I. (new series). (Recently published.)

Part 14.—Explorations in the Bone Cave of Ballynamintra, near Cappagh, County Waterford. By A. Leith Adams, M.B., LL.D., F.R.S., F.G.S. G. H. Kinahan, M.R.I.A. and R. J. Ussher. Plates IX. to XIV. (April, 1881.)

Part 15.—Notes on the Physical Appearance of the Planet Jupiter during the Season 1880–81. By The Earl of Rosse and Dr. Otto Boeddicker. Plate XV. (January, 1882.)

Part 16.—Photographs of the Spark Spectra of Twenty-one Elementary Substances. By W. A. Hartley, F.R.S.E., Professor of Chemistry, Royal College of Science, Dublin. Plates XVI., XVII., and XVIII. (February, 1882.)

Part 17.—Notes on the Physical Appearance of the Comets *b* and *c*, 1881, as observed at Birr Castle, Parsonstown, Ireland. By The Earl of Rosse and Otto Boeddicker, PH.D. Plate XIX. (*In the Press.*)

Part 18.—On the Laurentian Rocks of Donegal, and of other parts of Ireland. By Edward Hull, LL.D., F.R.S., &c., Director of the Geological Survey of Ireland. Plates XX. and XXI. (February, 1882.)

Vol. II. (new series).

Part 1.—Observations of Nebulæ and Clusters of Stars made with the Six-foot and Three-foot Reflectors at Birr Castle, from the year 1848 up to about the year 1878. Nos. 1 and 2. By the Right Hon. the Earl of Rosse, D.C.L. With Plates I. to IV. (August, 1879.) No. 3. With Plates V. and VI. (June, 1880.)

Part 2.—On Aquatic Carnivorous Coleoptera or Dytiscidæ. By Dr. D. Sharp. Plates VII. to XVIII. (April, 1882.)

PROCEEDINGS: *8vo., in parts, stitched.*

Vol. III. (new series).

Part 1.—Pages 1 to 32. (January, 1881.)
Part 2.—Pages 33 to 60. (April, 1881.)
Part 3.—Pages 61 to 150. (July, 1881.)
Part 4.—Pages 151 to 168. (October, 1881.)
Part 5.—Pages 169 to 301. (August, 1882.)
Part 6.—Pages 302 to 370. (December, 1882.)

THE

SCIENTIFIC PROCEEDINGS

OF THE

ROYAL DUBLIN SOCIETY.

VOL. III. (NEW SERIES). JULY, 1883. PART VII.

CONTENTS.

The Authors alone are responsible for all opinions expressed in their communications.

DUBLIN:

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1883.

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Royal Dublin Society.

FOUNDED, A.D. 1731. INCORPORATED 1749.

Evening Scientific Meetings.

The Evening Scientific Meetings of the Society and of the associated bodies (the Royal Geological Society of Ireland and the Dublin Scientific Club) are held in Leinster House on the third Monday in each month during the Session. The hour of meeting is 8 o'clock, P.M. The business is conducted in the undermentioned sections.

Section I.—PHYSICAL AND EXPERIMENTAL SCIENCES.
Secretary to the Section, R. J. MOSS, F.C.S.

Section II.—NATURAL SCIENCES (including Geology and Physical Geography).
Secretary to the Section, R. M'NAB, M.D.

Section III.—SCIENCE APPLIED TO THE USEFUL ARTS AND INDUSTRIES.
Secretary to the Section, HOWARD GRUBB, M.E., T.C.D.

Authors desiring to read papers before any of the sections of the Society are requested to forward their communications to the Registrar of the Royal Dublin Society (Mr. R. J. Moss), or to one of the Sectional Secretaries, *at least* ten days prior to each evening meeting, as no paper can be set down for reading until examined and approved by the Science Committee.

The copyright of all papers read becomes the property of the Society, and such as are considered suitable for the purpose will be printed with the least possible delay. Authors are requested to hand in their MS. in a complete form and ready for transmission to the printer.

XXXV.—ON MUSICAL SHORTHAND. By G. JOHNSTONE STONEY, M.A., D.Sc., F.R.S., a Vice-President of the R.D.S.

[Read June 19, 1882.]

Harmony may be studied either by those who aspire to become successful musical composers, or by those whose more modest aim is to play, to hear, and to enjoy to the utmost the compositions of others.

Where music is to be made the occupation of life, a few months more or less taken up by the preliminary studies may not much matter; but there can be no question that among the vast number of others who devote a part of their time to this delightful branch of art a very large number are deterred from attempting to acquire an adequate knowledge of harmony, and consequently are debarred from a great part of the enjoyment they might otherwise have, by the appearance of entanglement which the study in its early stages presents, and by the awkward nomenclature which encumbers the subject and adds unnecessarily to the appearance of obscurity and confusion.

Now, an attempted aid in such a case may either be merely a new burden on the memory, in which case it is only mischievous, or it may be like stepping-stones which enable the wayfarer to cross a stream which would otherwise stop his progress, unless he were willing to go a long distance out of his way for a bridge.

One such aid, the moveable Do, was at an early period advocated by a Dublin professor, the late Dr. Smith, Professor of Music in the University of Dublin,* and it has produced marvellous effects in England and Scotland under the name of the Tonic Sol-fa system of teaching singing; but it has as yet found little favour with musicians in Ireland. Yet there can be no doubt that the use of such convenient names for the notes of a scale as do, ray, me, fah, so la, te, instead of such awkward words as domi-

* See his "Treatise on the Theory and Practice of Music," 1853, p. 74.

nant, sub-dominant, supertonic, mediant, and so on, is a great help to the study of harmony, and also tends to prevent the objectionable practice into which many harmonists fall of thinking only in the key of C.

Another aid, and it is hoped a material aid, will be found by employing the symbols for chords suggested in this paper. They have been contrived so as to keep before the eye of the student as much information about the chord as possible. The form of the symbol tells him the contents of the chord, and its position tells him the relation of that chord to the other chords of the scale, and to the chords of all related scales, and how it should be modified to become a chord of any other scale. Great care has been taken to frame the symbols so that as many useful associations as possible shall be created by them, and in such a way as to blend naturally with the other associations which enable a student to master the intricacies of musical analysis.

For this purpose a straight line is used to designate a major chord, a curved line a minor chord, and a loop is used for the imperfect triad. Three positions also are employed—a vertical position, one sloping upwards, and one sloping downwards.

This enables us to represent with great simplicity the chords of a major key :— | represents the chord of the tonic (D or d m s of the Tonic Sol-faists), / represents the chord of the dominant (S or s t r), and \ the chord of the sub-dominant (F or f l d). The minor chords are represented as follows :—  chord of the sub-mediant (L or l d m),  chord of the super-tonic (R or r f l), and  the little-used chord of the mediant

(M or m s t). The imperfect triad on the leading note (T or t r f) is represented by a loop placed in the position sloping upwards to the right in order to associate it with the chord of the dominant, to which it is closely related. The seven chords of a major key will thus be in the positions indicated diagrammatically in Figure 1. The letters which denote these chords in the sol-fa system are placed beneath :—

FIG. 1.

T

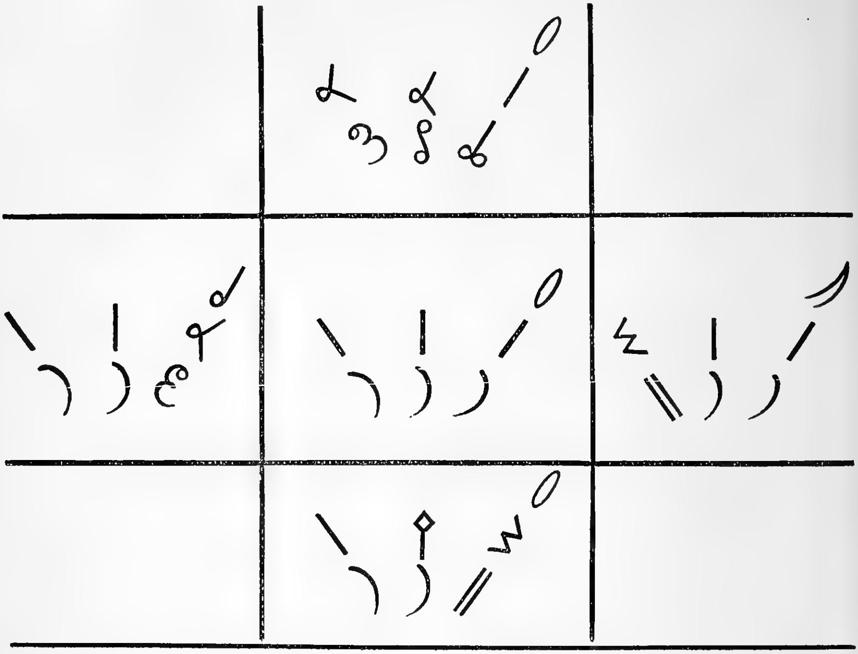
F D S

R L M

The inversions of these chords may be shown in two ways, either of which may be used. One of these methods is found most convenient when the symbols are written under music, the other if the analysis be written on a separate piece of paper. They will be described farther on; as also how dissonances and accidentals are to be indicated. One of the advantages of using these symbols is that the analysis may first be sketched in outline and added to afterwards so as to render it complete.

It will be convenient next to describe how to show the chords of related keys into which the music may pass for a time. Those most used by composers are the relative and tonic minors of the central key and the first sharp and first flat major keys. The symbols for these are represented in Figure 2, and are placed in the order shown in the subjoined index diagram.

FIG. 2.



Index to FIG. 2.

	Tonic minor key.	
First flat major key.	Central major key.	First sharp major key.
	Relative minor key.	

To understand these symbols it will be necessary to call to mind the changes which chords can be made to undergo by introducing sharps or flats, and we must provide suitable symbols to represent them. These, for our purpose, should be as suggestive as possible.

A major chord may undergo the following changes:—It will

become a minor chord if its third be flattened, or if its first and fifth be sharpened; it remains a major chord if all three notes be sharpened, or all three flattened ; it becomes an imperfect triad if its first be sharpened, or if its third and fifth be flattened, and finally it becomes an augmented triad if its fifth be sharpened or its first and third flattened. These changes we have now to mark by symbols. Those here suggested will tell what chord has been modified, into what kind of chord it has been altered, and by what flats or sharps the change has been effected. They will also indicate what situation the new chord has in any key into which it can enter.

This is effected by appending a loop to the lower end of the symbol, to denote that the first of the chord is flattened, to the middle to denote that its third is flattened, and to the upper end when its fifth is flattened. This enables us to indicate all the modifications which can be made by flattening any note or notes of the chord, and furnishes the following table:—

Fig. 3.

Table of chords produced by accidental flats.

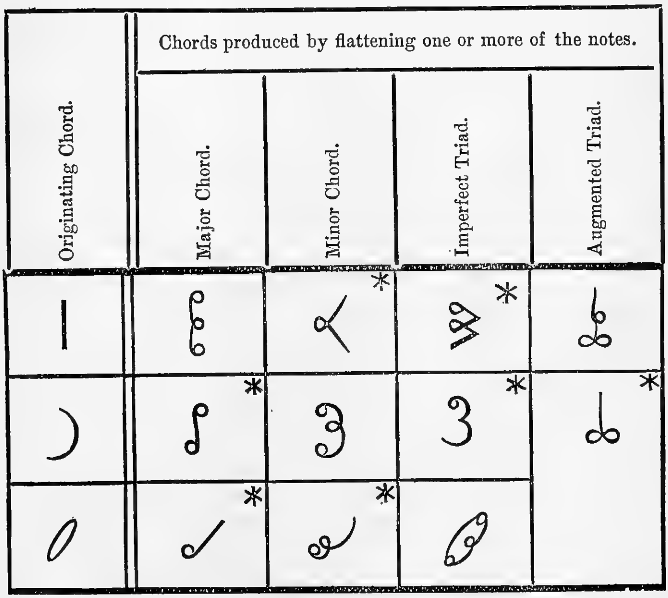
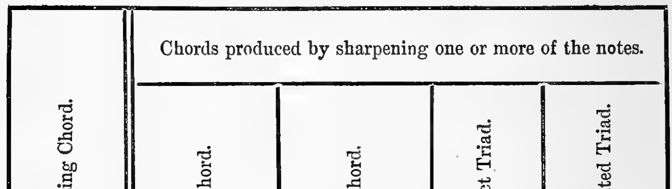


Figure 4 gives a table of the chords similarly produced by accidental sharps. In this table the intersection of two lines indicates where the sharp occurs, and in some of the squares a second symbol is suggested as more convenient to write than the first. This is not found in practice to diminish the significance of the symbol, as the student associates in his mind the two forms after he has written them out a few times. The symbols with three lines are used to signify that the first, third, and fifth of the parent chord are all sharpened. These symbols are only added to give completeness to the table, but are scarcely required in practice.

Fig. 4.

Table of chords produced by accidental sharps.



In fact, many of the chords in both tables do not occur in the transitions used by composers, and are only inserted to give completeness to the tables. Those most in use are distinguished by an asterisk, and with them the student soon becomes familiar. It should be stated that in the last column, that headed "Aug-

mented Triad," a double loop has been used for a flat, and a lozenge for a sharp. The awkwardness of these forms is immaterial, as the augmented triads are but little employed, and in the rare cases where they are introduced the peculiarity of the shape is useful to draw attention to them.

Beside the chords of these tables there is one other which may possibly occur, viz., the augmented triad produced from the imperfect triad by flattening its first and sharpening its third; it may be designated by , which indicates the accidentals that produce it.

The reader can now interpret the whole of Figure 2, and the student would do well to add to it in the corner squares the symbols for the tonic and relative minors of the first sharp and the first flat major keys.

A similar exercise should be written out by the student for music which begins in a minor key. It should contain the keys most related to it in some such order as the following:—

Major key, with one flat more.	Relative major key.	Major key, with one sharp more.
Minor key, with one flat more.	Central key, minor.	Minor key, with one sharp more.
Tonic major key of the foregoing minor.	Tonic major key.	Tonic major key of the foregoing minor.

In analysing music the symbols may be employed in two ways. When they are written under the music the student is advised to insert only those chords which he is unable freely to read off the music itself according as he plays it, and to diminish the number of symbols he inserts until he can wholly dispense with this assistance.

When used in this way the inversions of the chords are most conveniently indicated by a small u-shaped appendage, the appendage being placed opposite the middle of the symbol when the third of the chord is in the base, and beside the upper end of the

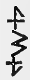
symbol when the fifth is in the base; thus,  represents s d m, the second inversion of the chord D; and  represents its first inversion, viz., m s d.

But when the analysis is written on a separate paper, as in Figure 5, the inversions are best indicated by inserting under the symbol of each inverted chord the sol-fa letter for the note on which it stands, in the way shown in that figure. It is sometimes also desirable in such analyses to add the crownings of the chords, *i.e.*, the uppermost notes.

It now remains to explain how dissonances are indicated. These are very simply introduced by adding oblique or cross lines, as follows:—

On major chords . . . 

On minor chords . . . 

On loops, &c. . . . .  

The lowest appendage in each case signifying a dissonating seventh, and the others in order the second, fourth, and sixth, the sixth being the uppermost. When a sharp occurs on a dissonating tone, a sharp angle may be used as the appendage instead of the simple cross line. Similarly a loop may be used when the dissonating tone is flattened. Thus the symbol  would signify the chord d m s re fe.

And again, the chord d m s ta, *i.e.*, D with a dissonating minor seventh, which makes it the chord of the dominant seventh in

the first flat key, may be represented by  , where the loop indicates that the dissonating tone is flattened. When a chord is inverted so that a dissonating tone is in the base, this may be indicated (in those cases in which the analysis is to be written under music) by doubling the little cross line that symbolizes the dissonating tone.

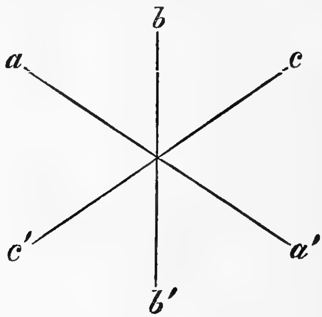
If the student should meet with a chord which is not provided for by any of these symbols, he should mark it in his analysis with an X, and make it a subject of separate study. The most important chords of this kind are those which contain the notes re (r sharp) and f. Mozart in particular has made extensive use of these chords (which are known under the very inappropriate names of the Italian, French, and German sixths), and the student will probably find it convenient to provide some special symbol for them.

This seems the proper place to point out how what may be called the circular chord is dealt with, viz., that tetrachord in the minor mode which consists of a series of minor thirds forming a complete circuit. It consists of the notes se t r f, and may be appropriately represented by a circle surrounding the symbol of the chord t r f. Examples of it in different keys will be found in Figure 5. There are three such chords on an instrument tuned like a piano according to the system of equal temperament, one of which is found in the relative and tonic minors of the central key, viz., se t r f, or t r f la (which are the same notes). It is indicated by  . Another consists of the notes re fe l d, or fe l d ma, and is found in the relative and tonic minors of the first sharp key. It may be represented by  . And the third, which consists of the notes de m s ta, or m s ta ra, is found in the relative and tonic minors of the first flat key. Its symbol is .

The reader will, no doubt, have observed that the symbols for

the tonic and submediant chords of the original key are vertical, its dominant harmonies sloping to the right, and its sub-dominant harmonies to the left.

In the first sharp key all these positions are shifted through sixty degrees to the right, and in the first flat key they lean sixty degrees to the left.



Thus *aa'* *bb'* and *cc'* are the directions of the sub-dominant tonic and dominant chords in the original key (compare with Figure 2). In the first sharp key the directions become *cc'* for the tonic, *aa'* for the dominant, and *bb'* for the sub-dominant; and in the first flat key they become *aa'* for the tonic, *bb'* for the dominant, and *cc'* for the sub-dominant.

When music passes into the first sharp key, the chords which before were the L D M and S chords of the original key become respectively the R F L and D chords of the new key, see Figure 2. It is often desirable to distinguish between these very different uses of the chords, which may be done by adding a hook round the bottom of the symbol when it belongs to the first sharp key. Similarly a loop may be added to the symbol of chords common to the original key and the first flat key when used in in the latter, *e.g.*, the same three notes would be denoted by when used for the D chord of the original key, by when used as the F chord of the first sharp key, and by when used as the S chord of the first flat key.

It now only remains to give a specimen of an analysis expressed in these symbols (vide p. 382). The piece chosen is the familiar opening theme of Beethoven's sonata with the Funeral March (Op. 26). It will be apparent how easily a sketch of the analysis may be first made, to be afterwards filled in by adding the changes of key, dissonances, inversions, and crowning notes. Waving ornaments and runs are indicated by an undulating line.

It will be understood that the object of this paper is not to suggest that these symbols should continue to be written by the student of harmony; the object is to enable him to dispense with all aids at the earliest possible moment, which will arrive when he can without effort read off the analysis by eye on seeing music, and by ear when he hears it—

> "Untwisting all the chains that tie
> The hidden soul of harmony."

This is an end well worth aiming at, for it is undoubtedly true as the same great poet has elsewhere said, that—

> "He that of those delights can judge, and spare
> To interpose them oft, is not unwise."

FIG. 5.—Andante from Beethoven's Sonata, with the Funeral March. Op. 26.

ROYAL DUBLIN SOCIETY.

HUNDRED AND FORTY-NINTH SESSION, 1879–80.

MINUTES OF PROCEEDINGS.

MONDAY EVENING, NOVEMBER 17TH, 1879.

Sections I. and III.—Physical and Experimental Science, and Applied Science.

(With which the "Dublin Scientific Club" is associated.)

W. F. BARRETT, F.R.S.E., in the Chair.

The following Communications were laid before the Section:—

G. F. FITZGERALD, F.T.C.D.—"On the possibility of originating Wave Disturbances in the Ether by means of Electric Forces."

(Transactions, Vol. I., Part X.)

R. J. MOSS, F.C.S.—"Note on some points in the Analyses of Commercial Superphosphates."

G. JOHNSTONE STONEY, D.SC., F.R.S.—"Report on the Progress of Science —Professor Henry Newton's Researches on Cometary Astronomy."

The following were exhibited:—

Photographs of the Sun. (Presented to the Society by M. Janssen.)

Photograph of a portion of the Solar Spectrum, illustrating Prof. Draper's discovery of Oxygen in the Sun. (Presented to the Society by W. Erck, LL.D.)

Section II.—Natural Science.

(With which the "Royal Geological Society of Ireland" is associated.)

Rev. Dr. HAUGHTON, F.R.S., in the Chair.

The following Communications were laid before the Section:—

G. ORMONDE STONEY, Captain 25th Regiment.—"On supposed Footprints on the Surface of a Rock near Mulrany, Co. Mayo."

Professor HULL, LL.D., F.R.S.—"Relation of the Carboniferous and Devonian Formations of the South of Ireland with those of North Devon."

(Transactions, Vol. I., Part XI.)

W. R. M'NAB, M.D.—" Note on the Root Hairs of *Azolla pinnata.*"

W. R. M'NAB, M.D.—" On Branched Hairs from the Stamen of *Tradescantia Virginica.*"

W. R. M'NAB, M.D.—" On some Abnormal Flowers of Primula."
(Proceedings, Vol. II., N.S.)

MONDAY EVENING, DECEMBER 15TH, 1879.

Sections I. and III.—Physical and Experimental Science, and Applied Science.

(With which the " Dublin Scientific Club " is associated.)

G. JOHNSTONE STONEY, D.SC., F.R.S., in the Chair.

The following Communications were laid before the Section:—

Professor W. NOEL HARTLEY, F.R.S.E., F.C.S.—" On the Relation of Chemical Structure to certain Optical Properties of Organic Substances."

HOWARD GRUBB, M.E., F.R.A.S—" On the New Astronomical Observatory, Cork."
(Proceedings, Vol. II., N.S).

JOHN R. WIGHAM—Exhibited the Albo-Carbon method for improving the illuminating power of Gas."

Section II.—Natural Science.

(With which the " Royal Geological Society of Ireland " is associated.)

Rev. MAXWELL H. CLOSE, M.A., in the Chair.

The following Communications were laid before the Section:—

V. BALL, M.A., F.G.S.—" On Spheroidal Jointing in Metamorphic Rocks in India and elsewhere, producing forms resembling *roches Moutonneés.*
(Proceedings, Vol. II., N.S.)

Rev. Dr. HAUGHTON, F.R.S.—" A comparison of the July and January Temperatures of Grinnell Land and Spitzbergen at present and in Miocene times, with an attempt to show that the Gulf Stream influences both."

PERCY EVANS FREKE.—" A Comparative Catalogue of the Birds found in Europe and North America."
(Proceedings, Vol. II., N.S.)

Monday Evening, January 19th, 1880.

Section I.—Physical and Experimental Science.

(With which the "Dublin Scientific Club" is associated.)

Howard Grubb, m.e., f.r.a.s., in the Chair.

The following Communications were laid before the Section :—

G. F. Fitzgerald, f.t.c.d.—"Note on the Conductivity of Tourmaline."

G. F. Fitzgerald, f.t.c.d.—"Note on the Construction of absolute Electrometers."

(Proceedings, Vol. II., N.S.)

Professor J. Emerson Reynolds, m.d.—Short Reports from the Chemical Laboratory of Trinity College :

No. 8.—"On the production of Specular Deposits of Lead Sulphide."

No. 9.—"On the Desulphuration of Thiocarbonide."

Professor W. F. Barrett, f.r.s.e.—"On Edison's Loud-speaking Telephone, and the Theory of its Action."

Section II.—Natural Science.

(With which the "Royal Geological Society of Ireland" is associated.)

G. Johnstone Stoney, d.sc., f.r.s., in the Chair.

The following Communications were laid before the Section :—

Rev. Dr. Haughton, f.r.s.—"On an Application of Prof. Rossetti's newly-discovered Law of Cooling to the question of Radiation of Heat from the Earth, and to problems of Geological Climate and Time."

(Proceedings, Vol. II., N.S.)

Dr. Frazer, f.r.c.s.i.—Exhibited *Bopyrus Squillarum*, parasitic on *Palæmon serratus*, and an Antler of Red Deer, obtained from the Dodder Bar in the River Liffey.

Monday Evening, February 16th, 1880.

Section I.—Physical and Experimental Science.

(With which the "Dublin Scientific Club" is associated.)

Wentworth Erck, ll.d., in the Chair.

The following Communications were laid before the Section :—

Charles E. Burton, b.a., f.r.a.s.—"Physical Observations of Mars, 1879-80."

(Transactions, Vol. II., Part XII.)

Prof. W. F. Barrett, F.R.S.E.—Notes from the Physical Laboratory of the Royal College of Science :

No. 1.—"On the cause of the vibration in the Trevelyan Rocker."

No. 2.—"On the effect of Temperature on the Illuminating Power of Coal Gas."

G. Johnstone Stoney, D.Sc., F.R.S.—"On a New Harmonic Relation between the Lines of Hydrogen."

Report on the Progress of Science.—Dr. J. Stoney, F.R.S.—"On Dr. Huggin's discovery of a Group of Spectral Lines characteristic of White Stars."

Section II.—Natural Science.

(With which the "Royal Geological Society of Ireland" is associated.)

G. H. Kinahan, M.R.I.A., President Royal Geological Society of Ireland, in the Chair.

The following Communications were laid before the Section:—

"Anniversary Address by the President of the Royal Geological Society of Ireland (1880.)"

(Proceedings, Vol. II., N.S.)

V. Ball, M.A., F.G.S.—"On the evidence in favour of the existence of Floating Ice in India, during the deposition of the Talchir (Permian) Rocks."

(Proceedings. Vol. II., N.S.)

Monday Evening, March 15th, 1880.

Sections I. and III.—Physical and Experimental Science, and Applied Science.

(With which the "Dublin Scientific Club" is associated.)

Professor Barrett, F.R.S.E., in the Chair.

The following Communications were laid before the Section:—

J. L. E. Dreyer, M.A., F.R.A.S.—"A Record of the Progress of Astronomy during the year 1879."

(Proceedings, Vol. II., N.S.)

G. Johnstone Stoney, D.Sc., F.R.S.—"Note on Maxwell's Theory of Stresses in Rarified Gases."

G. Johnstone Stoney, D.Sc., F.R.S.—"A simple Formula for the volume of Gas produced by a chemical reaction."

S. Hunter, F.R.A.S.—"On the absence of the Lunar Atmosphere, the origin of Saturn's Nebulary Ring, and the Zodiacal Light."

Arthur E. Porte—Exhibited a Telephone Exchange at work.

Section II.—Natural Science.

(With which the "Royal Geological Society of Ireland" is associated.)

Rev. Dr. HAUGHTON in the Chair.

The following Communications were laid before the Section :—

"On the question of Suicide among Bees." Being the subject of two Letters from JOHN LUBY, Esq., LL.D., to Rev. Professor Haughton, M.D., F.R.S., F.T.C.D.
(Proceedings, Vol. II., N.S.)

A. B. WYNNE, F.G.S.—"Notes on some points in the Physical Geology of the Dingle and Iveragh Promontories."
(Proceedings, Vol. II., N.S.)

MONDAY EVENING, APRIL 19TH, 1880.

Section I.—Physical and Experimental Science.

(With which the "Dublin Scientific Club" is associated.)

J. EMERSON REYNOLDS, M.D., in the Chair.

The following Communications were laid before the Section :—

G. JOHNSTONE STONEY, D.SC., F.R.S.—"On a possible Cosmical Cause for the Gap in the series of Atomic Weights."

G. JOHNSTONE STONEY, D.SC., F.R.S.—"Report on the Progress of Science—Lord Rayleigh's Investigations on the Theory of the Spectroscope."

G. JOHNSTONE STONEY, D.SC., F.R.S.—"A Direct Vision Spectroscope."

Captain ABNEY'S Photograph of the Spectrum exhibiting the Natural Colours was exhibited.

WENTWORTH ERCK, LL.D., F.R.A.S.—Exhibited a new Form of constant Bichromate Battery.

S. YEATES—Exhibited Noë's Thermo-Electric Battery, and an "Aladin" Lamp.

Section II.—Natural Science.

(With which the "Royal Geological Society of Ireland" is associated.)

Rev. M. H. CLOSE, M.A., in the Chair.

The following Communications were laid before the Section :—

THOMAS PLUNKETT, Esq.—"On a Trap-dyke in Poll-a-Phuca Mountain, Co. Fermanagh."

W. WILLIAMS, Esq.—"Changes of Climate as indicated by the Lacustrine Deposits of Ireland."

W. R. M'NAB, M.D.—Exhibited Models of Insectivorous Plants, and Engler's Diagram Apparatus for Illustrating the Structure of Flowers.

Wednesday Evening, May 19th, 1880.

(Instead of the third Monday of the Month, which on this occasion fell on Whit-Monday).

Section I.—Physical and Experimental Science.

(With which the "Dublin Scientific Club" is associated.)

Charles Cameron, M.D., in the Chair.

The following Communications were laid before the Section:—

Professor J. Emerson Reynolds, M.D.—"On a New Process for Coating Metallic and other surfaces with reflecting layers of Galene."

G. F. Fitzgerald, F.T.C.D.—"Note on Fluorescence."

(Proceedings, Vol. II., N.S.)

G. F. Fitzgerald, F.T.C.D.—"On the possibility of originating Wave Disturbances in the Ether by means of Electric Forces." (No. 2).

(Transactions, Vol. III., Part XIII.)

G. F. Fitzgerald, F.T.C.D.—Report on the Progress of Science—Prof. Minchin's Investigations in Phototelegraphy.

Section II.—Natural Science.

(With which the "Royal Geological Society of Ireland" is associated).

William Ramsay M'Nab, M.D., in the Chair.

The following Communications were laid before the Section:—

Richard M. Barrington, LL.B.—"On the Introduction of the Squirrel into Ireland."

(Proceedings, Vol. II., N.S.)

V. Ball, M.A., F.G.S.—"On the Occurrence of Gold in India, with special reference to the recent discoveries of it in the Madras Presidency."

(Proceedings, Vol. II., N.S.)

E. T. Hardman, F.C.S.—"On a Nickleiferous Serpentine from Sligo, containing a large quantity of Magnetite."

E. T. Hardman, F.C.S.—"On a Travertine from Co. Sligo, containing a considerable amount of Strontia."

(Proceedings, Vol. III., N.S., Part I.)

E. T. Hardman, F.C.S.—Exhibited part of the Skull and other bones of a Pre-historic Man, discovered in a Kist-vaen at Coolaney, near Sligo, with associated Food-urn; also a second Urn found near the same place.

Monday Evening, June 21st, 1880.

Section I.—Physical and Experimental Science.

(With which the "Dublin Scientific Club" is associated.)

R. C. R. Tichborne, ph.d., f.c.s., in the Chair.

The following Communications were laid before the Section :—

Howard Grubb, m.e., f.r.a.s.—"On a new Simple Form of Equatorial Telescope for Students' Use."

C. A. Cameron, m.d.—"On the action of Water on Mercuric Sulphate."
(Proceedings, Vol. II., N.S.)

H. N. Draper, f.c.s.—"On the influence of Albumen on the Crystallization of Nitrate of Urea."

J. Emerson Reynolds, m.d., f.r.s.—Exhibited Meyer's Vapour Density Apparatus, and Dr. Dupré's Mode of Testing Wine for foreign colouring matter.

Section II.—Natural Science.

(With which the "Royal Geological Society of Ireland" is associated).

Edward Hull, ll.d., f.r.s., in the Chair.

The following Communications were laid before the Section :—

V. Ball, m.a., f.g.s.—"On the mode of Occurrence and Distribution of Diamonds in India."
(Proceedings, Vol. II., N.S.)

Thomas Plunkett, m.r.i.a.—"On Chert in the Limestone of Knockbeg, Co. Fermanagh.
(Proceedings, Vol. II., N.S.)

ROYAL DUBLIN SOCIETY.

HUNDRED AND FIFTIETH SESSION, 1880–81.

MINUTES OF PROCEEDINGS.

Monday Evening, November 15th, 1880.

Sections I. and II.—Physical and Experimental Science, and Applied Science.

With which the "Dublin Scientific Club" is associated.

Wentworth Erck, LL.D., F.R.A.S., in the Chair.

The following Communications were laid before the Section:—

C. E. Burton, B.A., F.R.A.S., and Howard Grubb, M.E., F.R.A.S.—"A New Form of Ghost Micrometer for Astronomical Instruments."
(Proceedings, Vol. III., N.S., Part I.)

William Smith, C.E.—" Preliminary Note on the Manufacture of Paper from Purple Melic Grass (*Molinia cœrulea*).
(Proceedings, Vol. III., N.S., Part I.)

G. F. Fitzgerald, F.T.C.D.—" Recent Advances in Physical Science":—

1. Captain Galton's mode of determining the heights and distances of Clouds.
2. Professor Osborne Reynolds's Theory of how Oil stops the propagation of Waves on the surface of Water.

Section III.—Natural Science.

(With which the "Royal Geological Society of Ireland" is associated.

G. H. Kinahan, President R.G.S.I., in the Chair.

The following Communications were laid before the Section:—

R. J. Ussher and Dr. Leith Adams, F.R.S.—" Explorations in the Bone Cave of Ballynamintra, near Cappagh, Co. Waterford;" with a description of the Physical Features of the vicinity, by G. H. Kinahan, President, R.G.S.I.
(Transactions, Vol. I., Part XIV., *in press.*)

Percy E. Freke.—" North American Birds in Europe."
(Proceedings, Vol. III., N.S., Part I.)

David M'Ardle.—" Notes on some new and rare Irish Hepaticæ."
(Proceedings, Vol. III., N.S., Part I.)

SCIENTIFIC PUBLICATIONS OF THE ROYAL DUBLIN SOCIETY.

TRANSACTIONS: *Quarto, in parts, stitched.*

Vol. I. (new series). (Recently published.)

Part 22.—On the Energy expended in Propelling a Bicycle. By G. JOHNSTONE STONEY, D.SC., F.R.S., a Vice-President of the Society; and G. GERALD STONEY. With Plates XXXIX., XL., and XLI. (January, 1883.)

Part 23.—On Electromagnetic Effects due to the Motion of the Earth. By GEORGE FRANCIS FITZGERALD, M.A., F.T.C.D., Erasmus Smith's Professor of Experimental Science in the University of Dublin. (January, 1883.)

Part 24.—On the Possibility of Originating Wave Disturbances in the Ether by Means of Electric Forces:—Corrections and Additions. By GEORGE FRANCIS FITZGERALD, M.A., F.T.C.D. (January, 1883.)

Part 25.—On the Fossil Fishes of the Carboniferous Limestone Series of Great Britain. By JAMES W. DAVIS, F.G.S., &c., &c. With Plates XLII. to LXV. (Communicated by the EARL of ENNISKILLEN.) (July, 1883.) With Title Page to Volume.

Vol. II. (new series).

Part 1.—Observations of Nebulæ and Clusters of Stars made with the Six-foot and Three-foot Reflectors at Birr Castle, from the year 1848 up to about the year 1878. Nos. 1 and 2. By the Right Hon. the EARL OF ROSSE, D.C.L. With Plates I. to IV. (August, 1879.) No. 3. With Plates V. and VI. (June, 1880.)

Part 2.—On Aquatic Carnivorous Coleoptera or Dytiscidæ. By Dr. D. SHARP. Plates VII. to XVIII. (April, 1882.) With Title Page to Volume.

PROCEEDINGS: *8vo., in parts, stitched.*

Vol. III. (new series).

Part 1.—Pages 1 to 32. (January, 1881.)
Part 2.—Pages 33 to 60. (April, 1881.)
Part 3.—Pages 61 to 150. (July, 1881.)
Part 4.—Pages 151 to 168. (October, 1881.)
Part 5.—Pages 169 to 301. (August, 1882.)
Part 6.—Pages 302 to 370. (December, 1882.)
Part 7.—Pages 371 to 382, with Title Page, &c. (July, 1883.)

Fig.I.

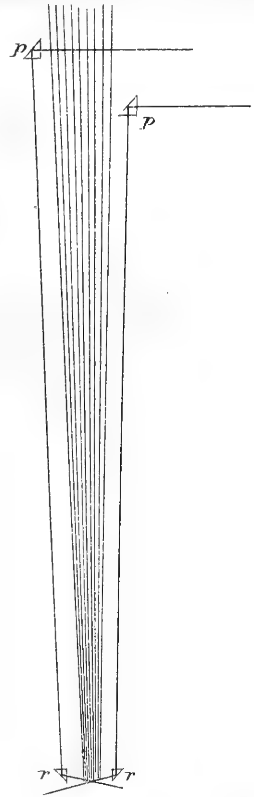


Fig.II.

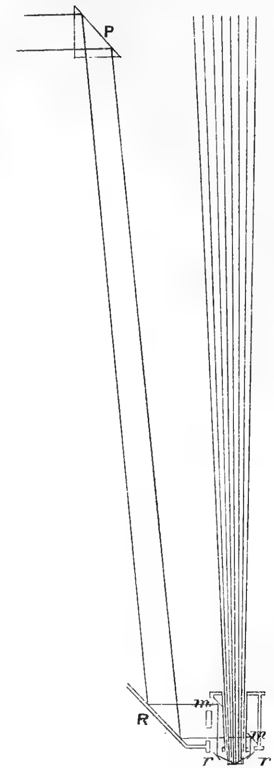


Fig. III.

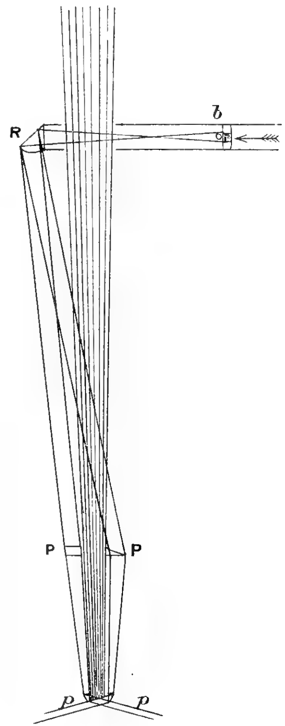


Fig. IV.

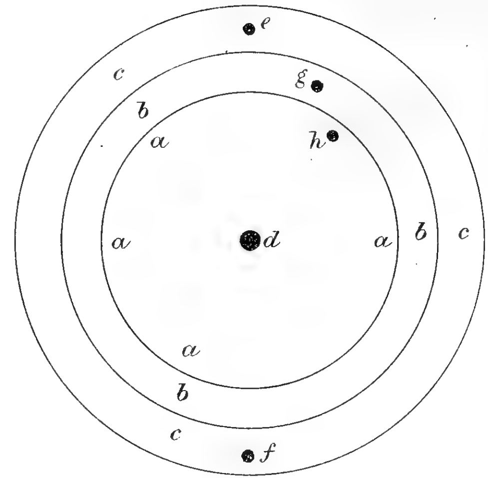


Fig V.

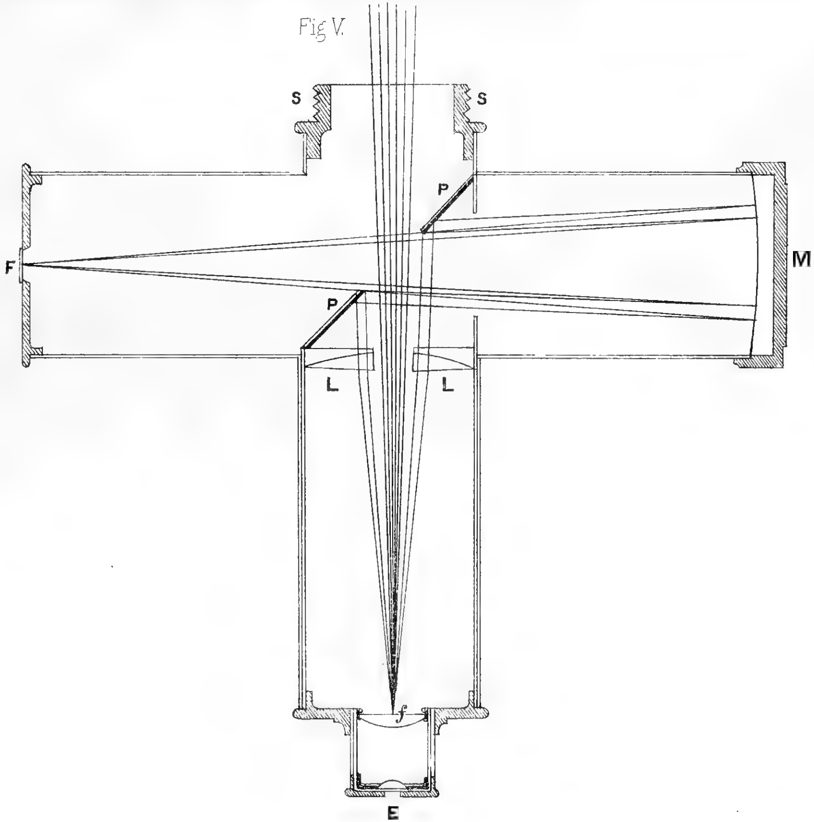


Fig VI

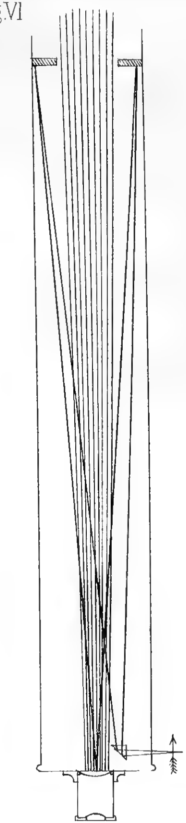


Fig VII.

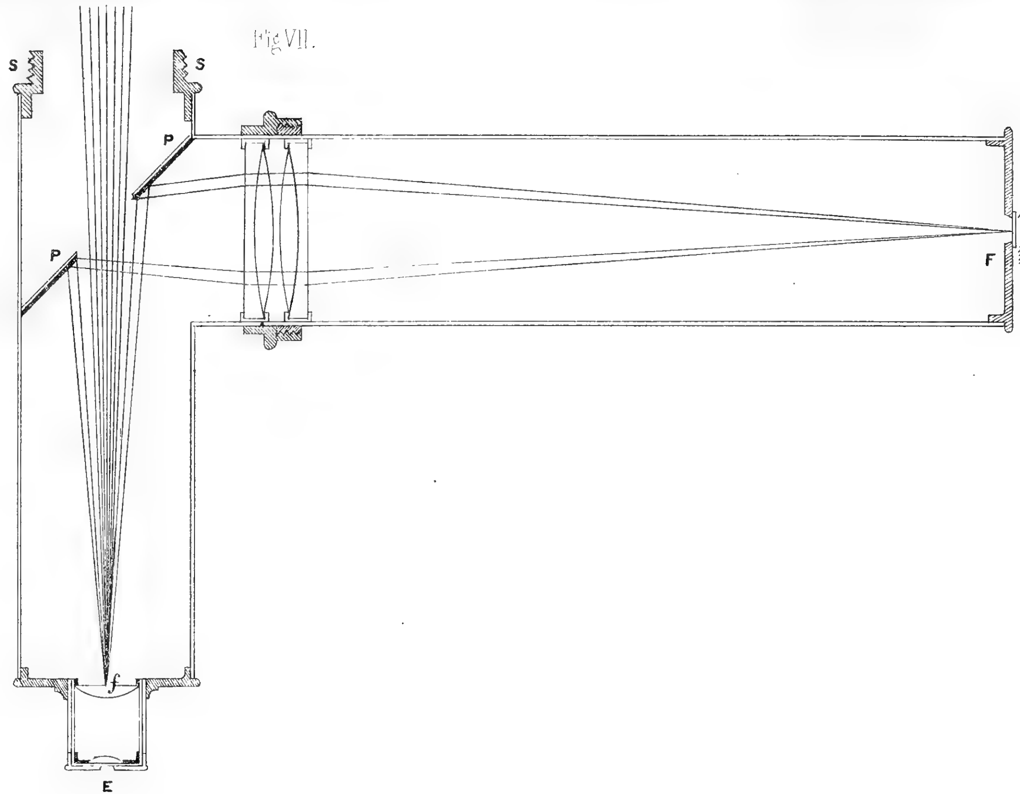


Fig. 1.

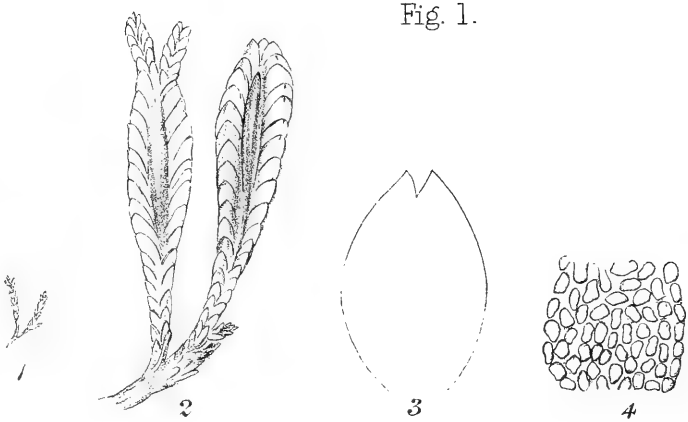
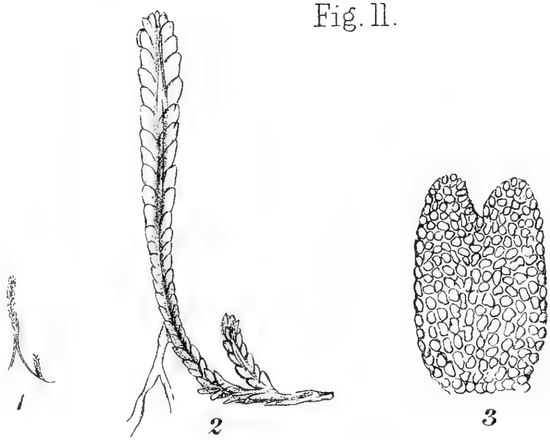


Fig. II.



D. McArdle, del.

Forster & Co. Dublin.

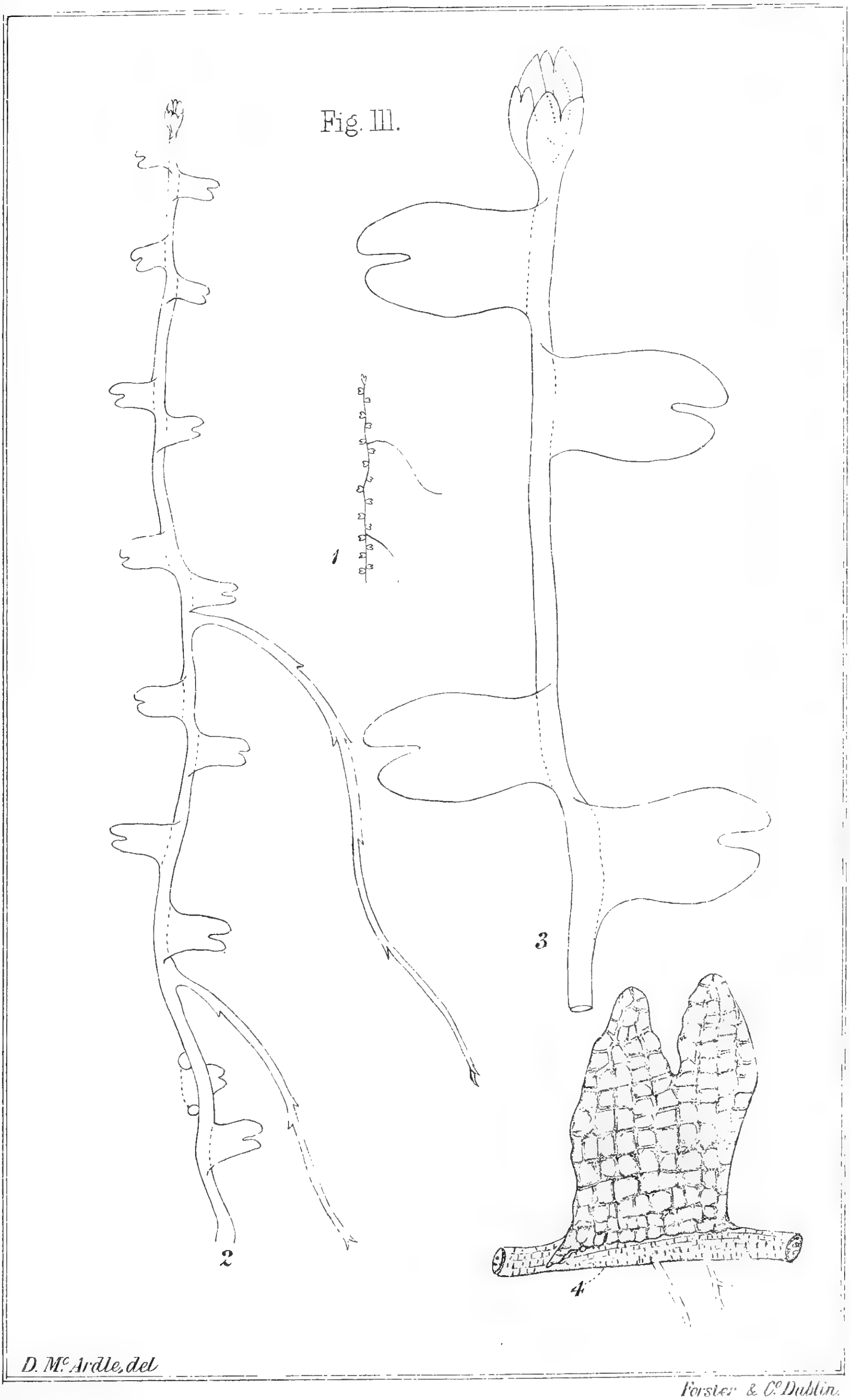


Fig. III.
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2
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D. McArdle, del
Forster & Co. Dublin.

ALÆOZOIC ROCKS OF IRELAND

Plate VII.

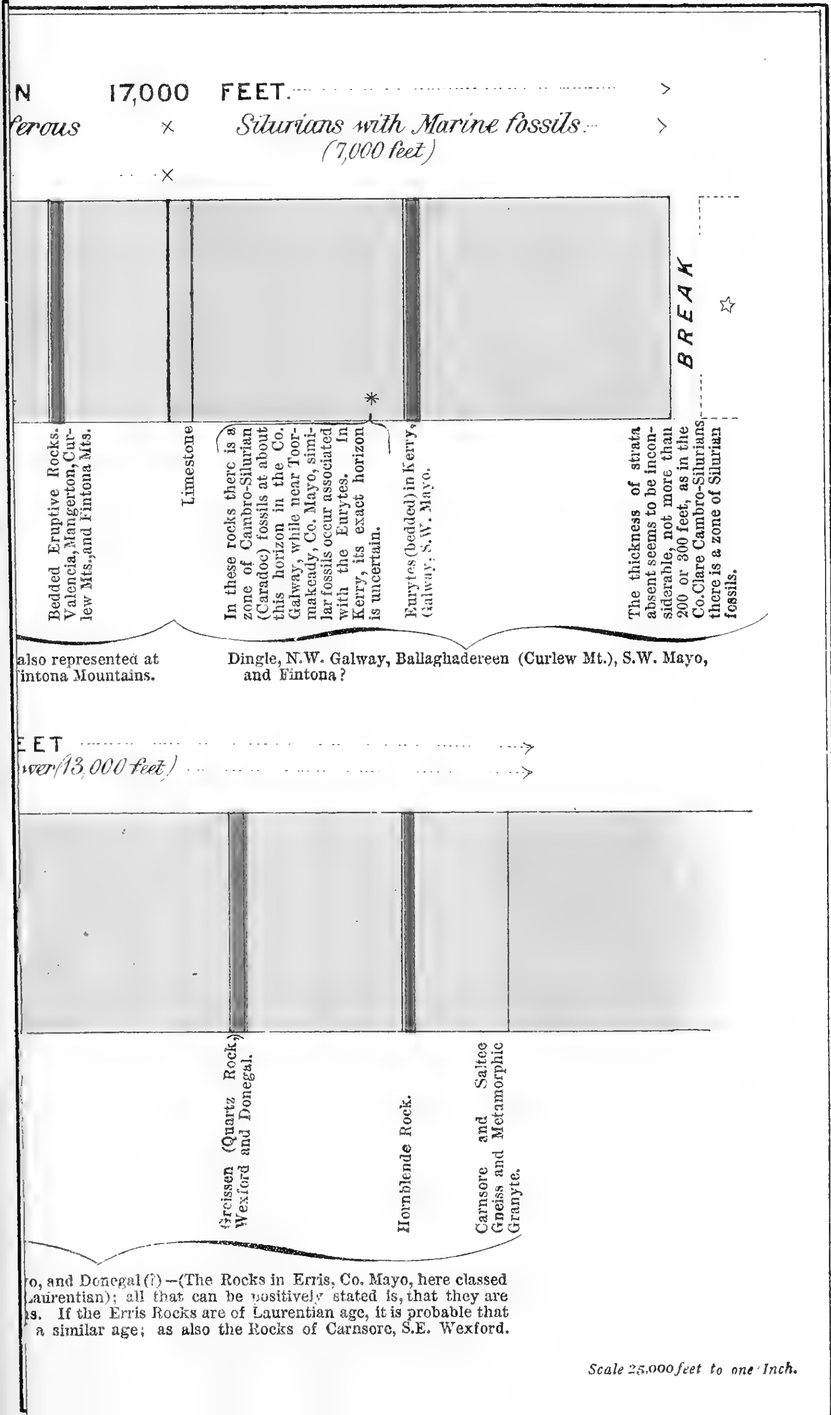
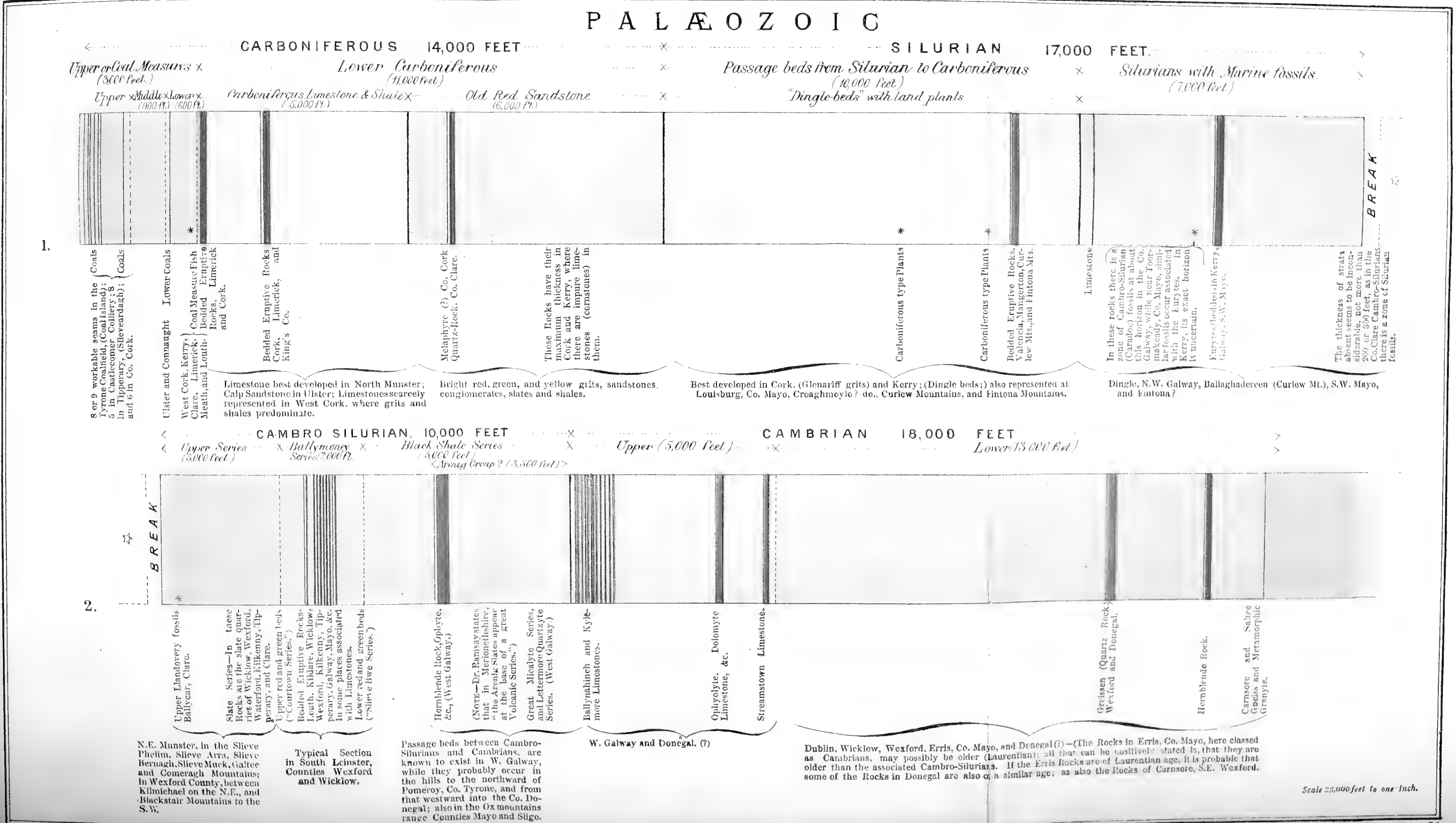


DIAGRAM ILLUSTRATING THE THICKNESSES AND NEARLY CONTINUOUS SEQUENCE OF THE PALÆOZOIC ROCKS OF IRELAND



Forster & Co. Lith. 2, Crow St.

DI)ZOIC AND CAINOZOIC ROCKS,

)NS.

In no place do all th
Rarely do any of the di
and usually each is muc
estuarine deposits is of
the low land or "Red B
Neagh beds are best d
also been found in the
and sands with seams o

The Eruptive Series a
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thickness, at a height o
is a zone about 250 fe
Basal Series is more u
limestone. It often co
beds of Lignyte or Iron

These Rocks have su
place is the full thickn
best developed, the Whi

This small thickness
Zones of Belemnites a
A. planorbis, and a low

The Rhœtic Beds are
The Triassic Beds s
adjoining Belfast Loug
siderable thickness of
and near Kingscourt, C
in them. Near Ardtre
seem to be interbedded

Very little is know
exposed at Cultra, on
in the Lagan Valley.

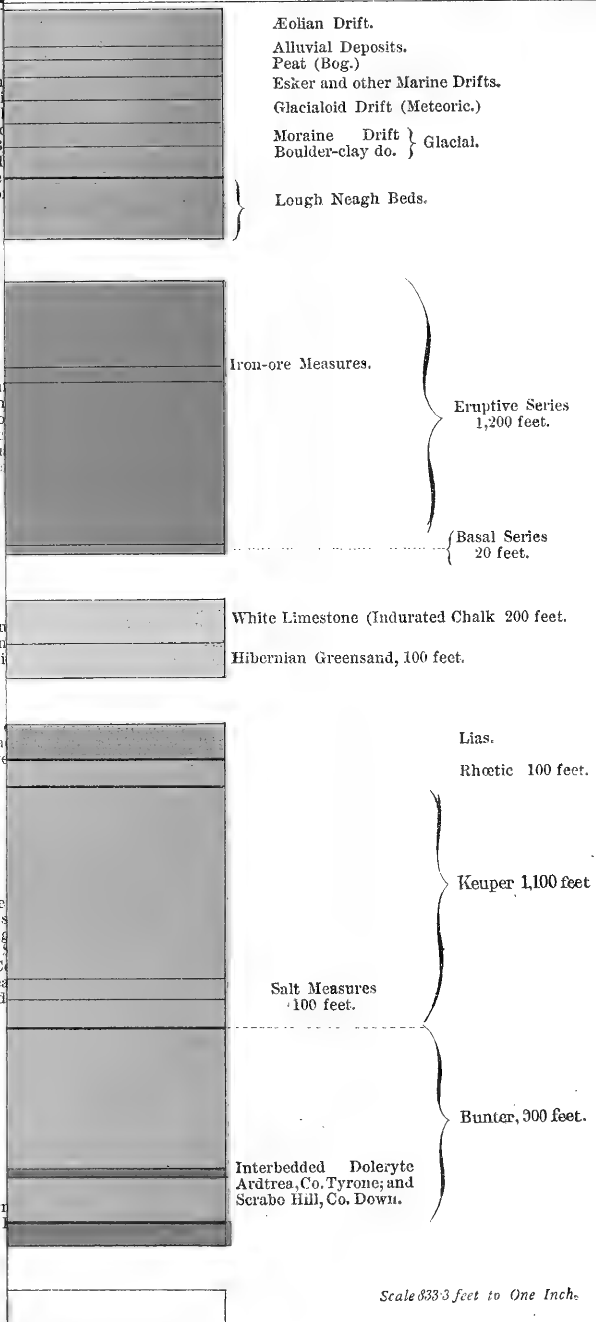

DIAGRAM ILLUSTRATING THE THICKNESSES OF THE IRISH MESOZOIC AND CAINOZOIC ROCKS, ALSO THE SUPERFICIAL ACCUMULATIONS.

In no place do all the Superficial Accumulations occur together. Rarely do any of the different Drifts exceed 100 feet in thickness, and usually each is much less. The Alluvium in some of the ancient estuarine deposits is of considerable thickness. The Peat in some of the low land or "Red Bog" is of considerable thickness. The Lough Neagh beds are best developed near Lough Neagh, but they have also been found in the Co. Tipperary; they consist of plastic clays and sands with seams of Lignyte.

The Eruptive Series are nearly solely bedded Dolerytes and Tuffs. In places there is a zone of Iron Ore Measures, from 1 to 60 feet in thickness, at a height of about 800 feet, while in other places there is a zone about 250 feet lower. Lignyte occurs in places. The Basal Series is more usually a conglomerate, but in places it is a limestone. It often contains plant remains in shaly beds, or even beds of Lignyte or Iron ore.

These Rocks have suffered considerably from denudation. In no place is the full thickness found, because where the Greensand is best developed, the White Limestone has been considerably denuded.

This small thickness of Lias is considered by Tate to represent the Zones of Belemnites acutus, Ammonites Bucklandi, A. angulatus, A. planorbis, and a lower Zone.

The Rhœtic Beds are thickest at Larne, Co. Antrim.
The Triassic Beds seem to be best developed in S.E. Antrim, adjoining Belfast Lough. Near Carrickfergus, they contain a considerable thickness of Salt measures, while near Coagh, Co. Tyrone, and near Kingscourt, Co. Cavan, deposits of Gypsum have been found in them. Near Ardtrea, Tyrone, and at Scrabo Hill, Co. Down, there seem to be interbedded Dolerytes.

Very little is known about the Permian; it is very imperfectly exposed at Cultra, on Belfast Lough; in the Co. Tyrone, and perhaps in the Lagan Valley.

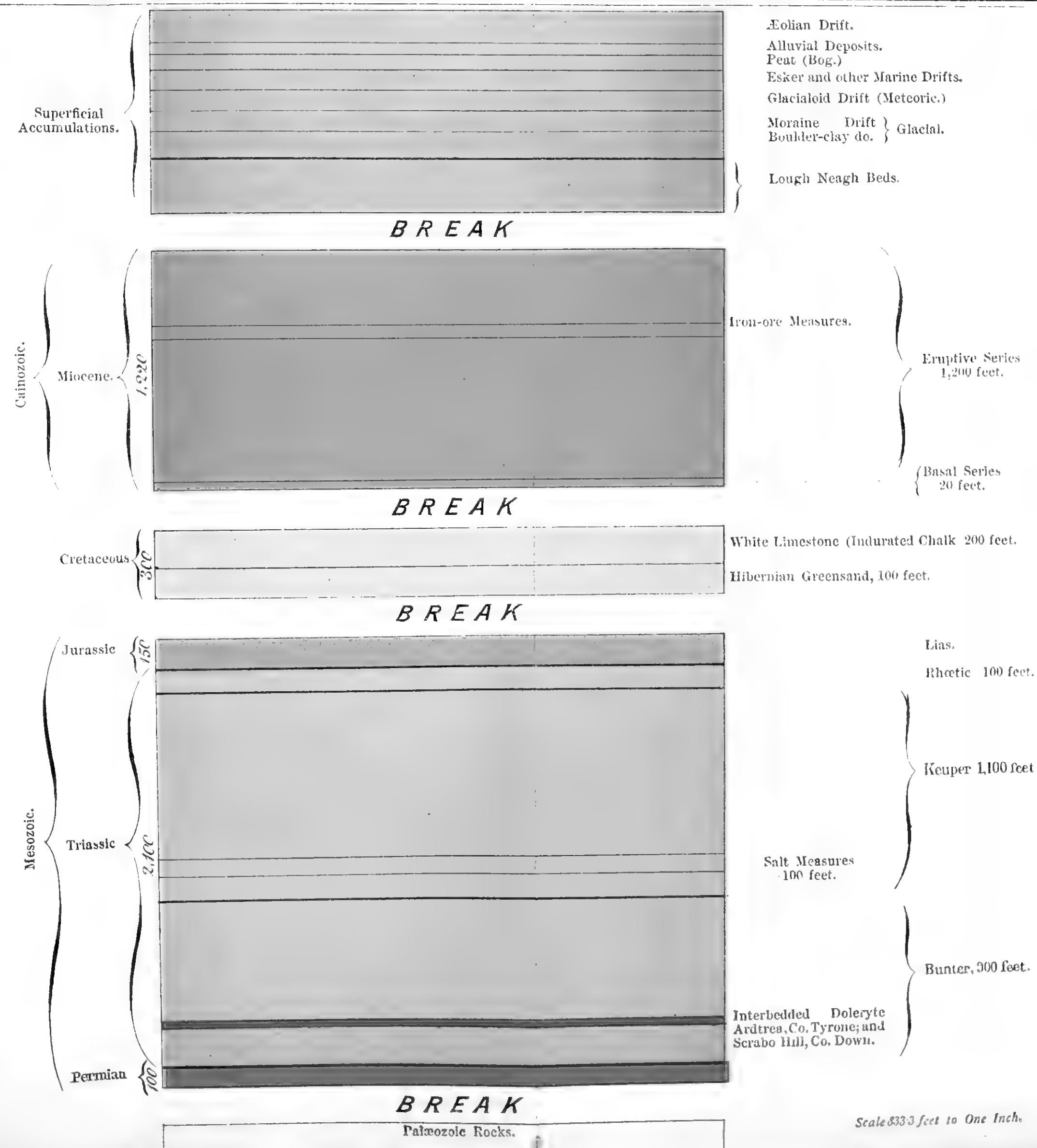

FIG. 1.

FIG. 2.

FIG. 3.

FIG. 4.

FIG. 5.

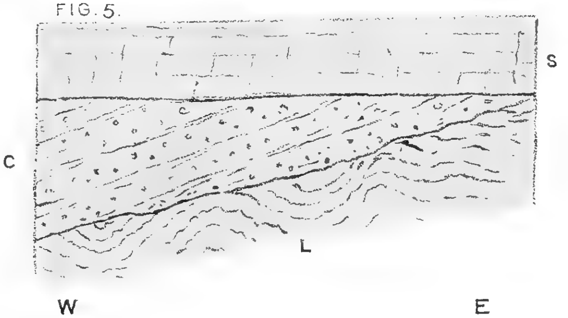

FIG. 6.

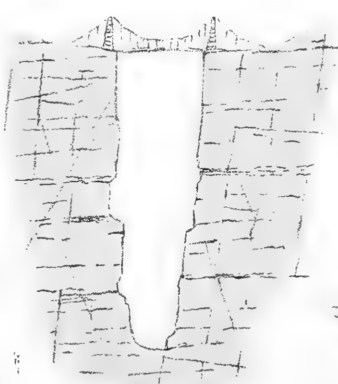

FIG. 7.

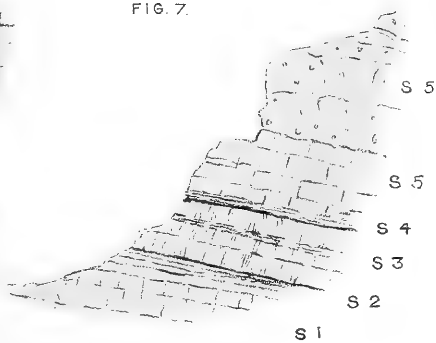

FIG. 8

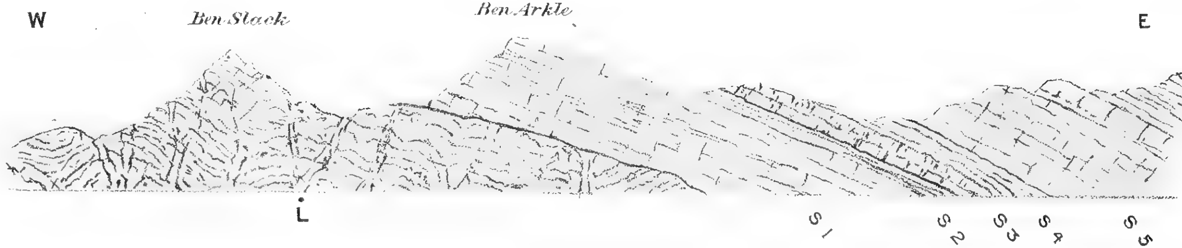
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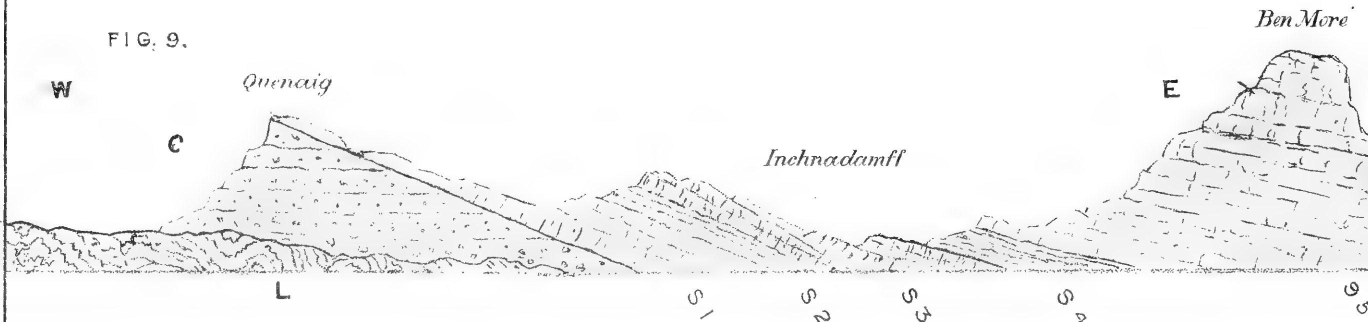
FIG. 9.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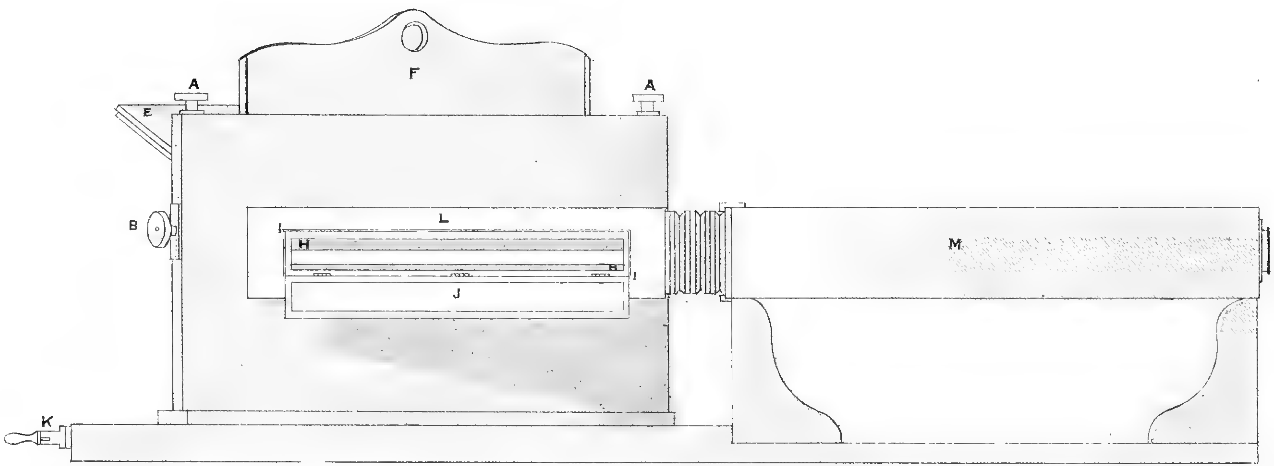
CAMERA.

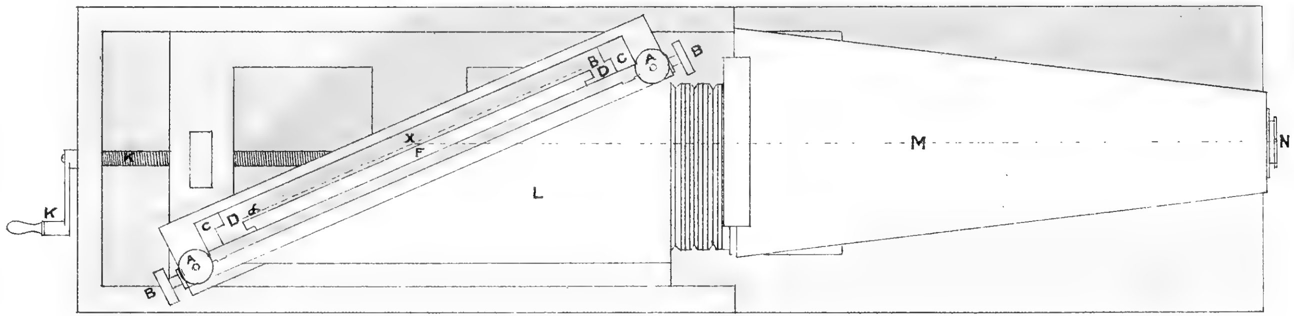
FOR PHOTOGRAPHING ULTRA-VIOLET SPECTRA

Scale 1/6th.



ELEVATION

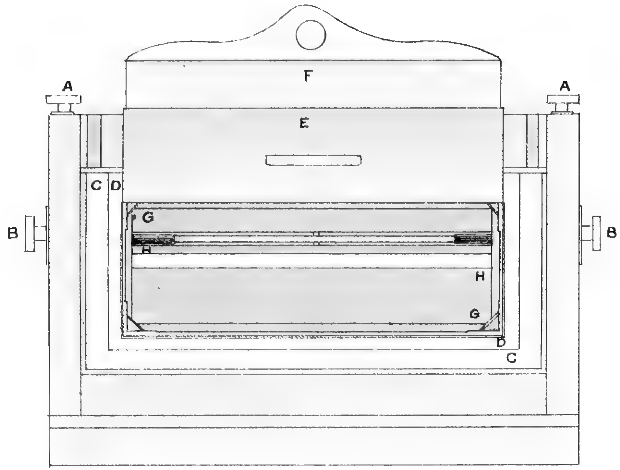
Forster & Co., Lith, Dublin



PLAN

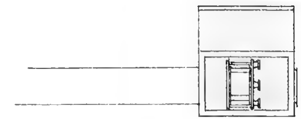
Scale 1/6 th

Forster & Co., Lith, Dublin



BACK OF DARK CHAMBER OPEN

Scale 1/6th.



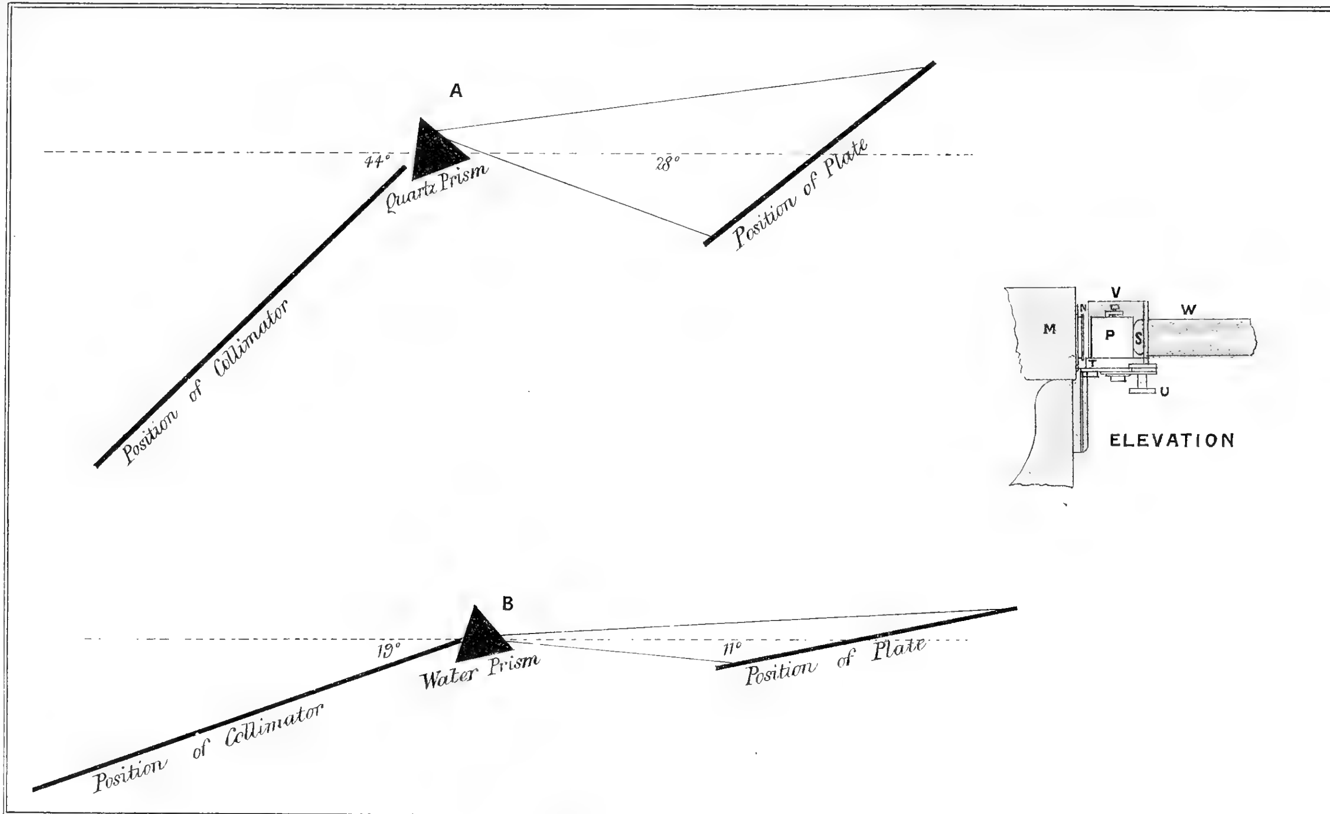
END OF COLLIMATOR

Elevation.

Plan

QUARTZ CELL.

Forster & Co., Lith, Dublin



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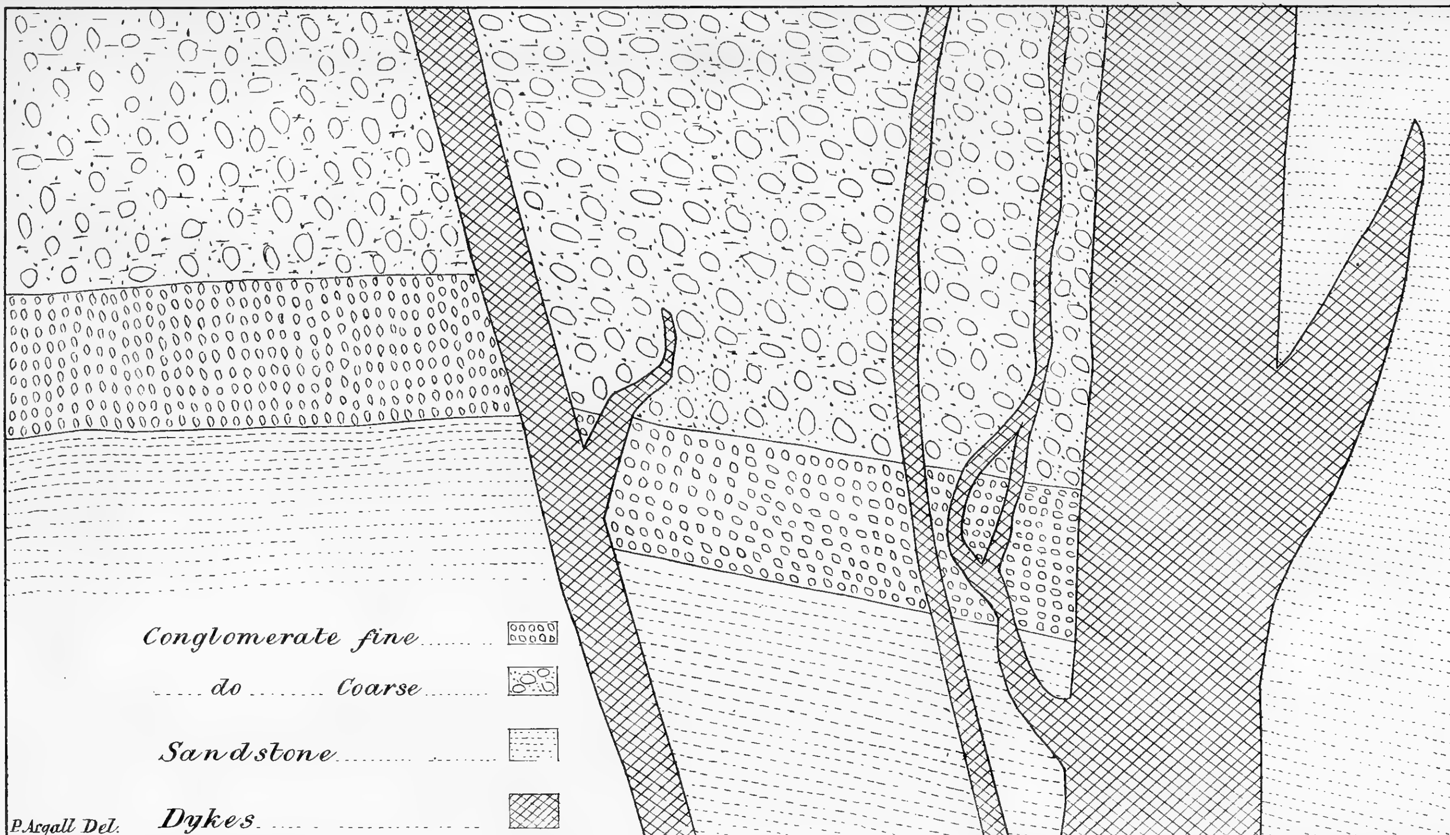
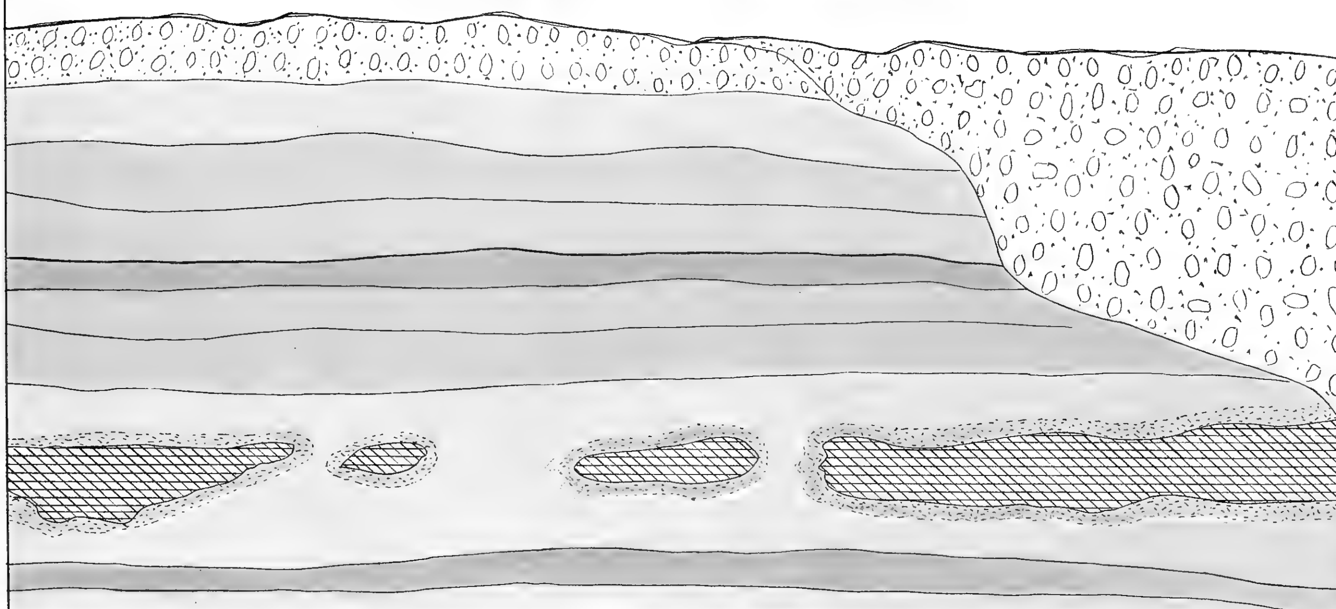


Forster & Co. Lith, Dublin.

SECTION OF DYKES AND SHOOTS IN RED BAY QUARRY.

BOTTOM BEDS OF IRON MEASURES.



P. Argall Del

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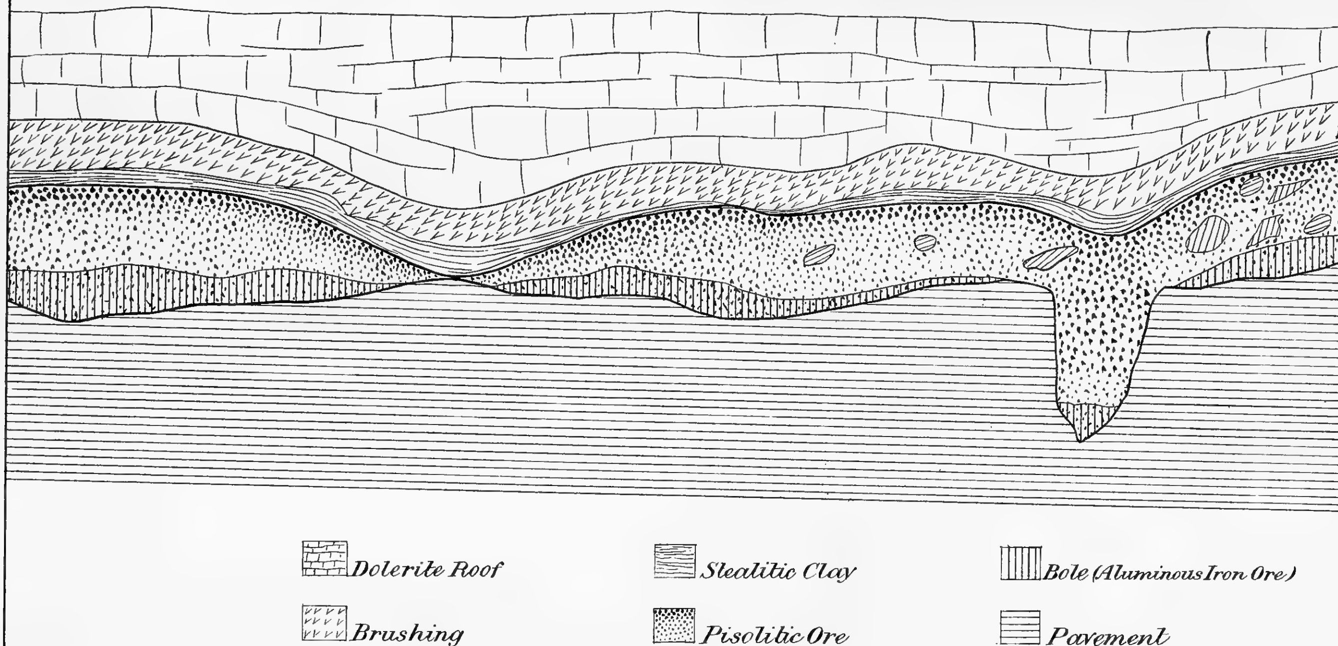
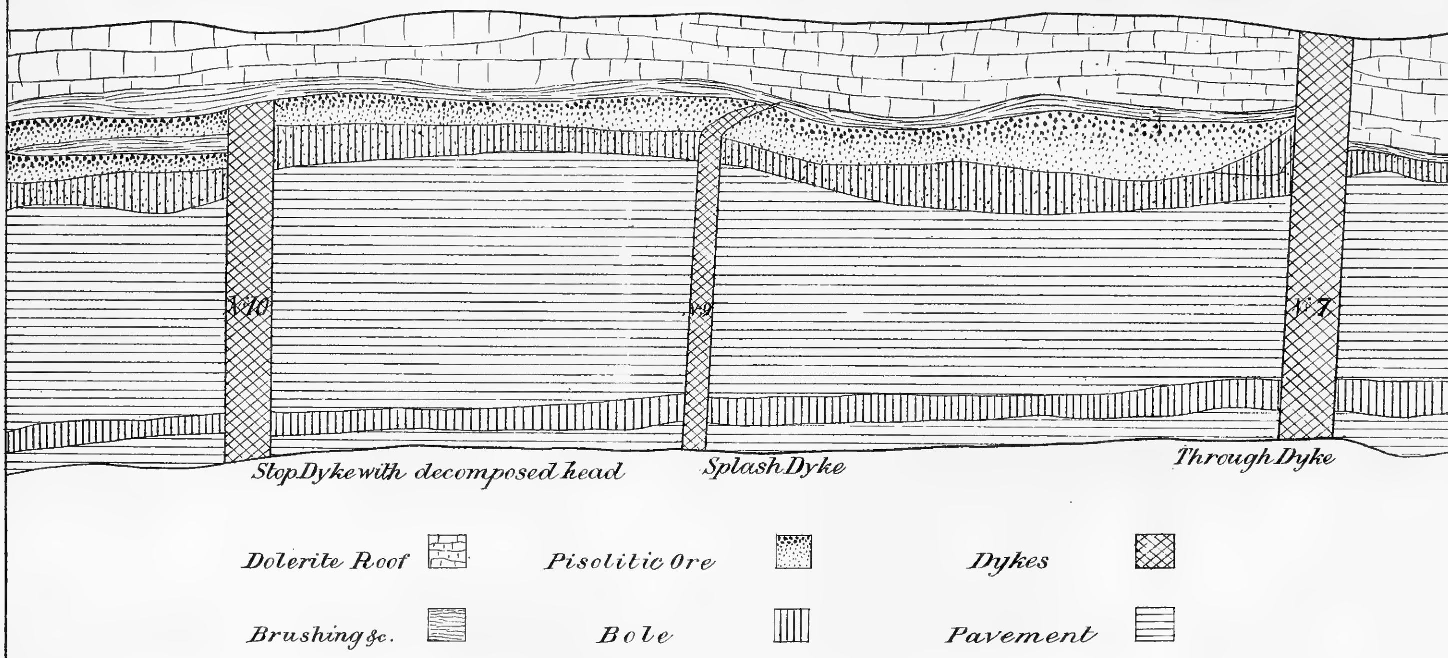
Section of Iron Ore Deposit, showing unconformability between the Bole, the Pavement, &c.



P. Argall Del

Forster & Co. Lith, Dublin.

SECTION ILLUSTRATING THE THREE KINDS OF DYKES.

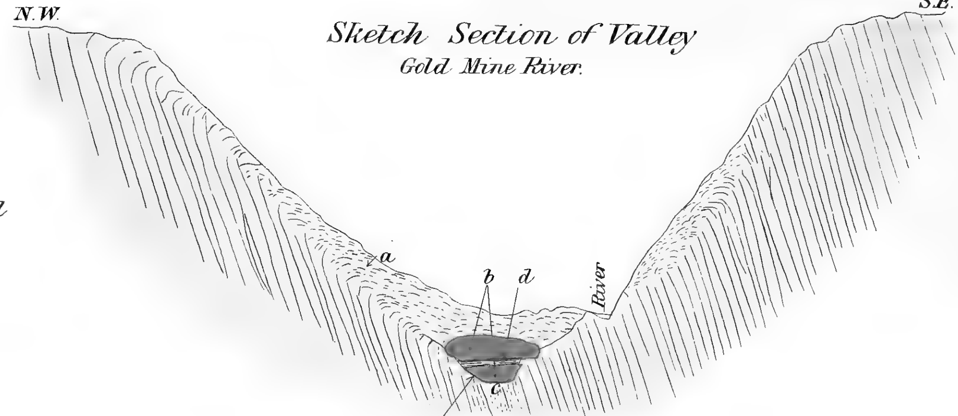


P. Argall Del

Forster & Co. Lith. Dublin.

Fig. 1.

Sketch Section of Valley
Gold Mine River.



INDEX

a. Local drift

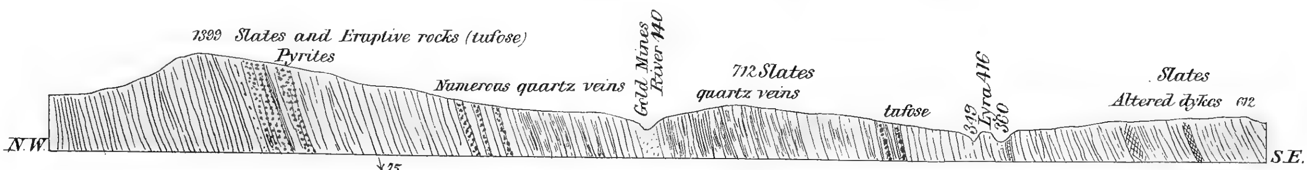
b Auriferous gravel

c. Old River bed

d. A bed of Clay

f. Bed Rock Slate

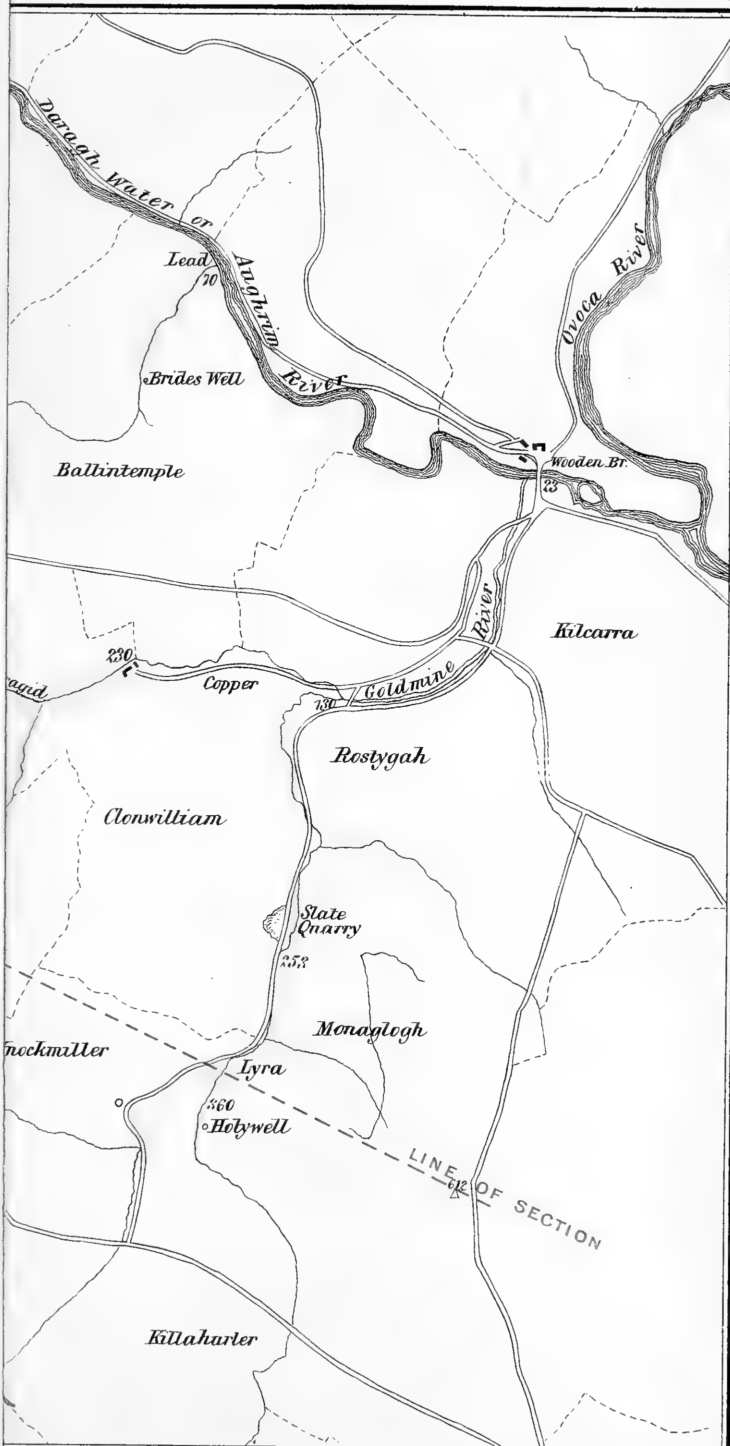
Fig. 2.



Section across district
Scale 2 inches 1 Mile

Forster & Co. Lith, Dublin.

G. A. Kinahan. 1882.



G.A. Kinahan. 1882.

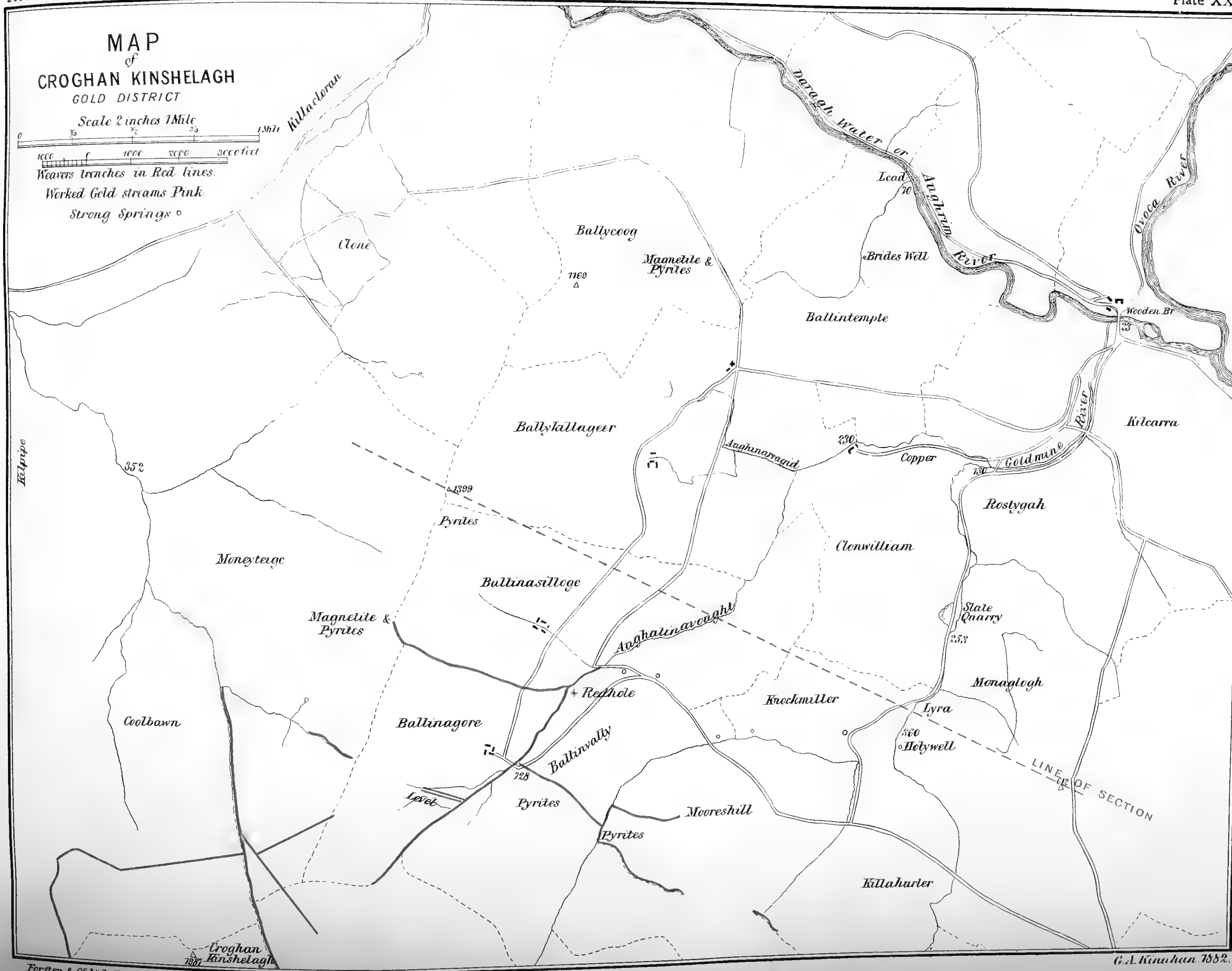
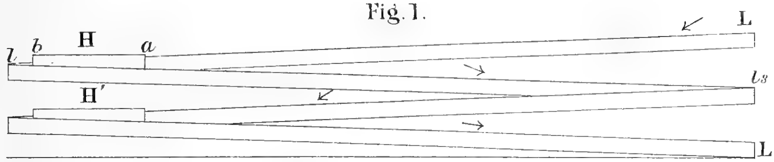
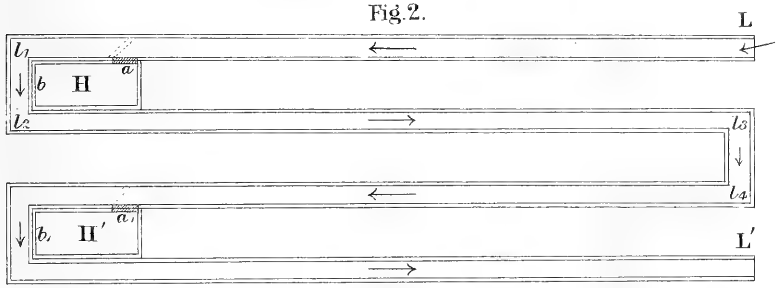

MAP
of
CROGHAN KINSHELAGH
GOLD DISTRICT
Scale 2 inches 1 Mile
Weavers trenches in Red lines.
Worked Gold streams Pink.
Strong Springs
Killacloran
Daragh Water or Aughrim River
Ovoca River
Lead
Ballycoog
Magnetite & Pyrites
1169
Clone
Brides Well
Ballintemple
Wooden Br
Kilpipe
352
Ballytallageer
Aughinavragid
230
Copper
Goldmine River
Kilcarra
1399
Pyrites
Rostygah
Moneyteige
Clonwilliam
Ballinasilloge
Magnetite & Pyrites
Slate Quarry
Aughatinavought
Redhole
Knockmiller
Monaglogh
Lyra
Coolbawn
Ballinagore
Ballinvally
360
Holywell
LINE OF SECTION
728
Level
Pyrites
Mooreshill
Pyrites
Killahurler
Croghan Kinshelagh
1987
G.A. Kinahan 1882.
Forster & Co. lith, Dublin.

Fig. 1.



ELEVATION

Fig. 2.

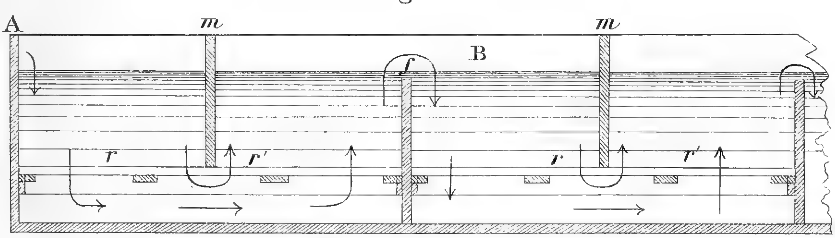


PLAN

Diagram representing the disposition of the launders

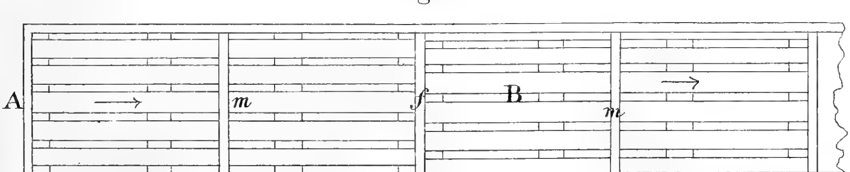
Form of launder used underground at Cronebane.

Fig. 3.



SECTION

Fig. 4.



PLAN

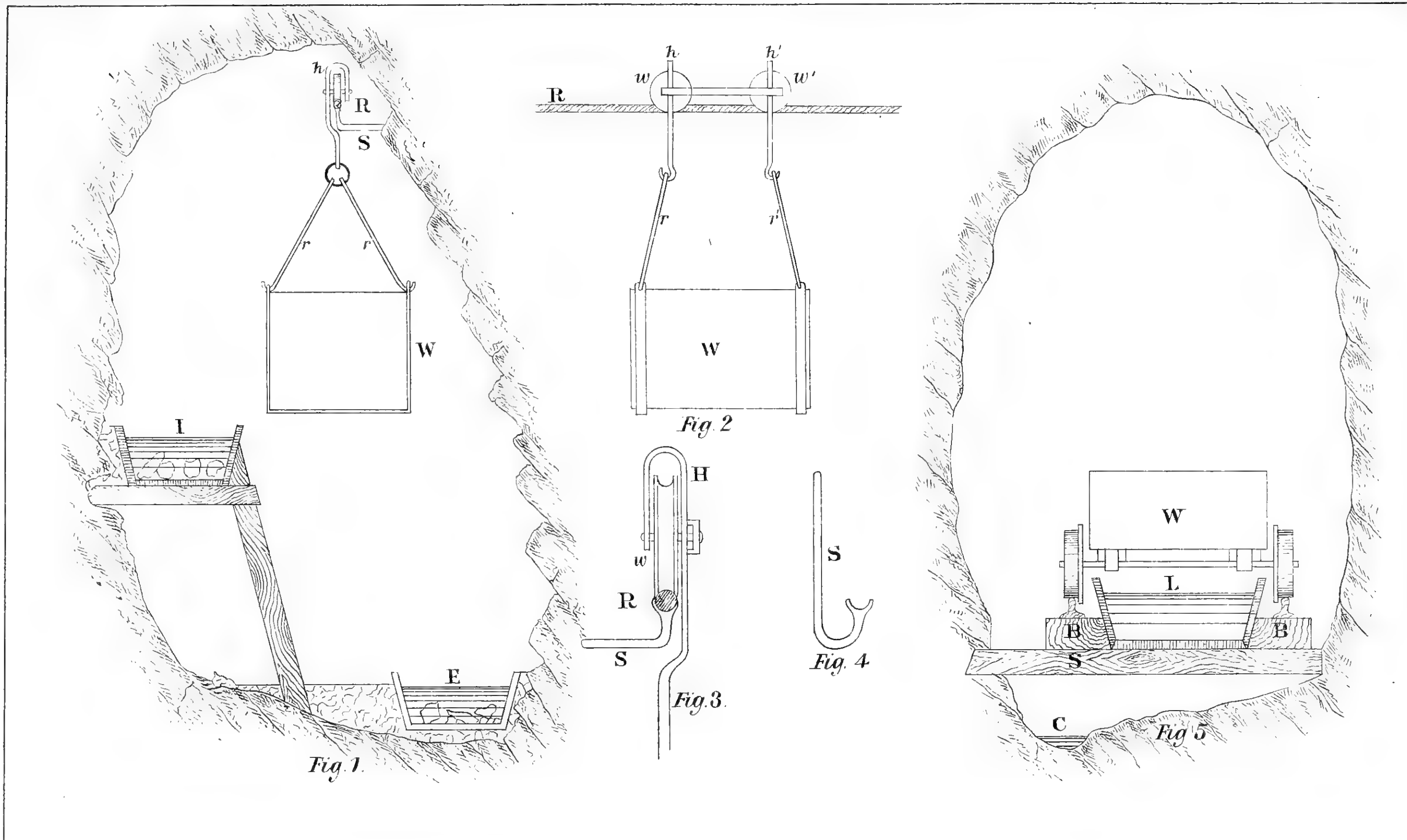
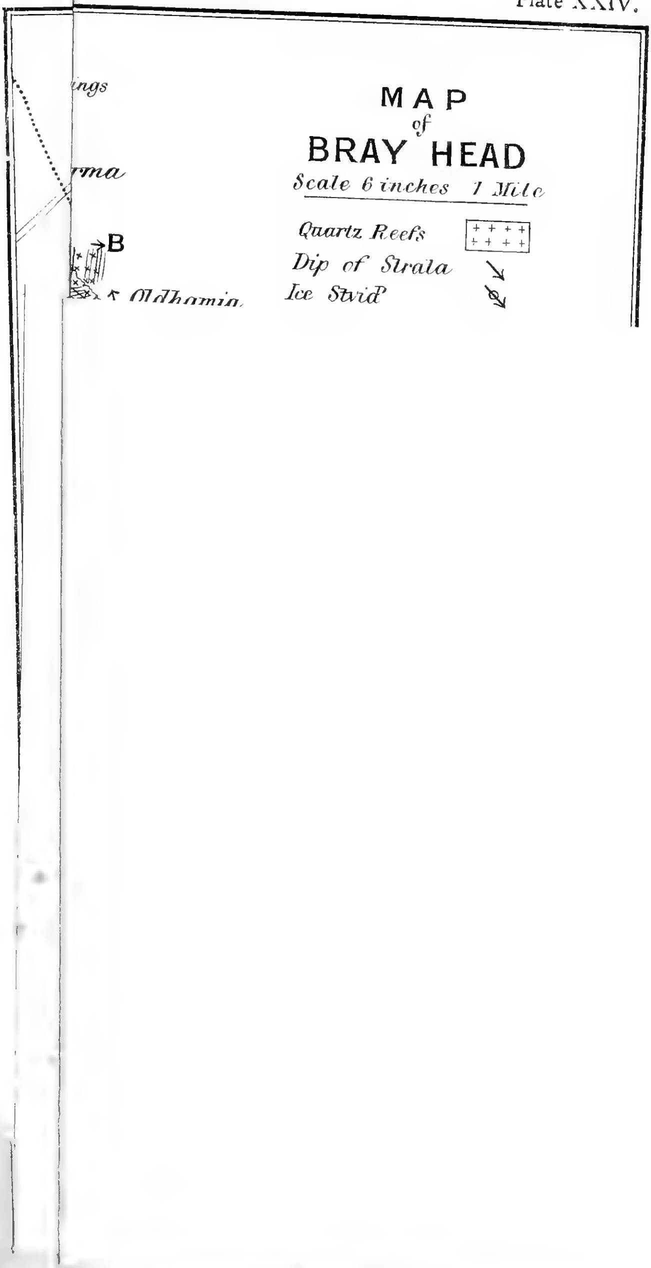
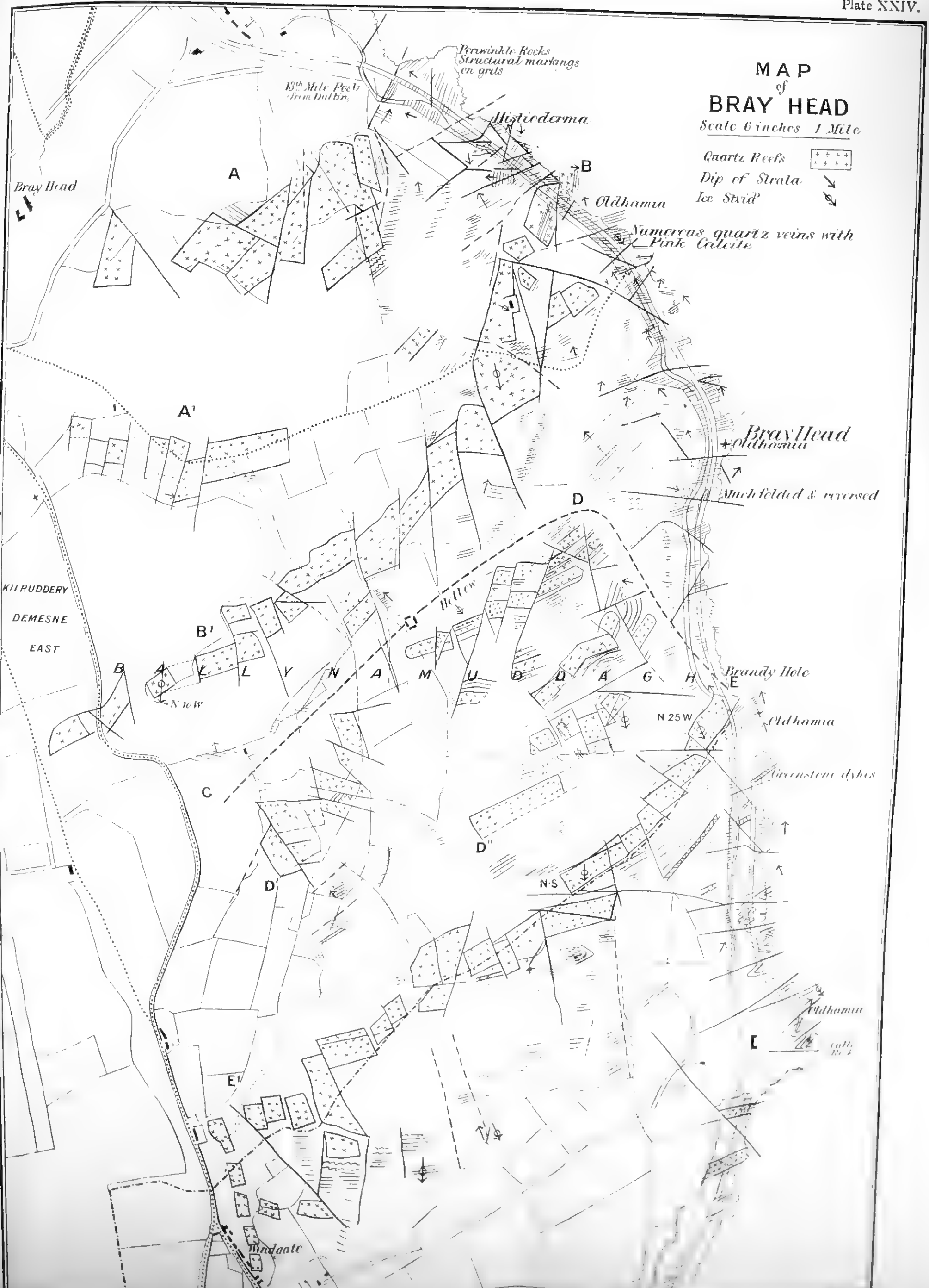


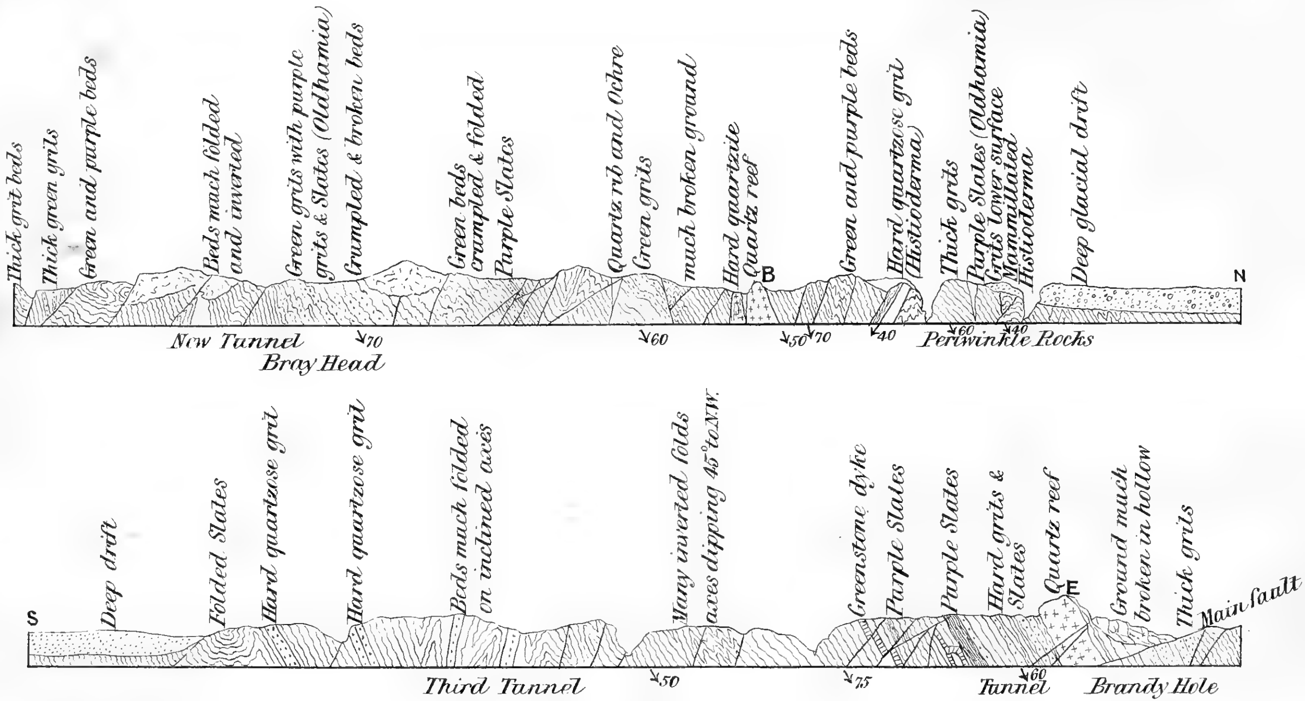
Fig. 1. Fig. 2. Fig. 3. Fig. 4. Fig. 5.

Forster & Co. lith. Dublin. P. A. & G. A. K. delt.


MAP
of
BRAY HEAD
Scale 6 inches 1 Mile
Quartz Reefs
Dip of Strata
Ice Striæ
ings
rma
B
Oldhamia



MAP of BRAY HEAD
Scale 6 inches 1 Mile
Quartz Reefs
Dip of Strata
Ice Striæ
Periwinkle Rocks Structural markings on grits
13th Mile Post from Dublin
Histioderma
Oldhamia
Numerous quartz veins with Pink Calcite
Bray Head
Much folded & reversed
Brandy Hole
Greenstone dykes
Hollow
KILRUDDERY DEMESNE EAST
B A L L Y N A M U D D A G H
N 10 W
N 25 W
N·S
Windgate
A
A'
B
B'
C
D
D'
D''
E
E'

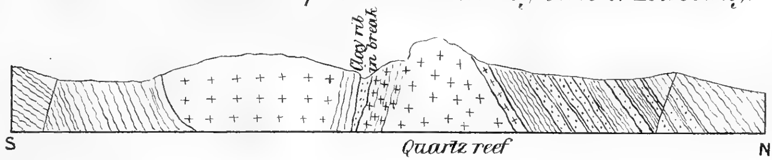


Section along shore line Bray Head. Scale 6 Inches = One Mile.

Forster & Co. Lith. Dublin. G. A. K.

Fig. 1.

Section of Northern quartz reef along line of Railway.



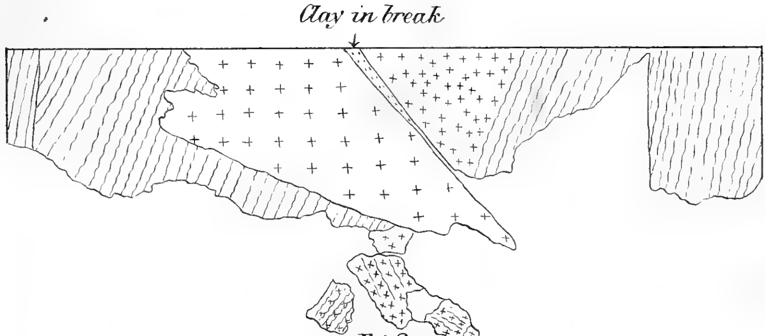
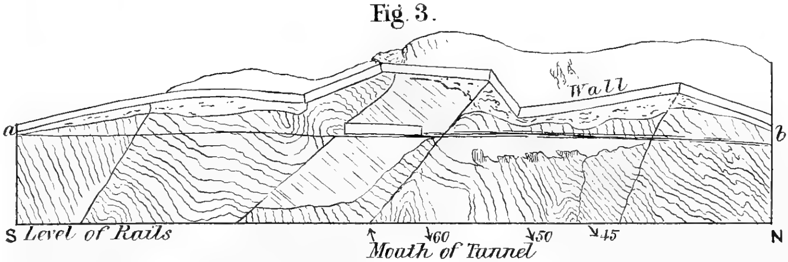


Fig. 2.

Plan of quartz reef from Railway to shore line.

Fig. 3.



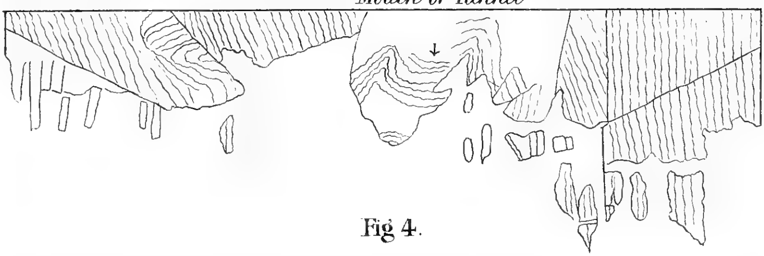


Fig 4.

Plan and Sketch Section of rocks at Bray Head.

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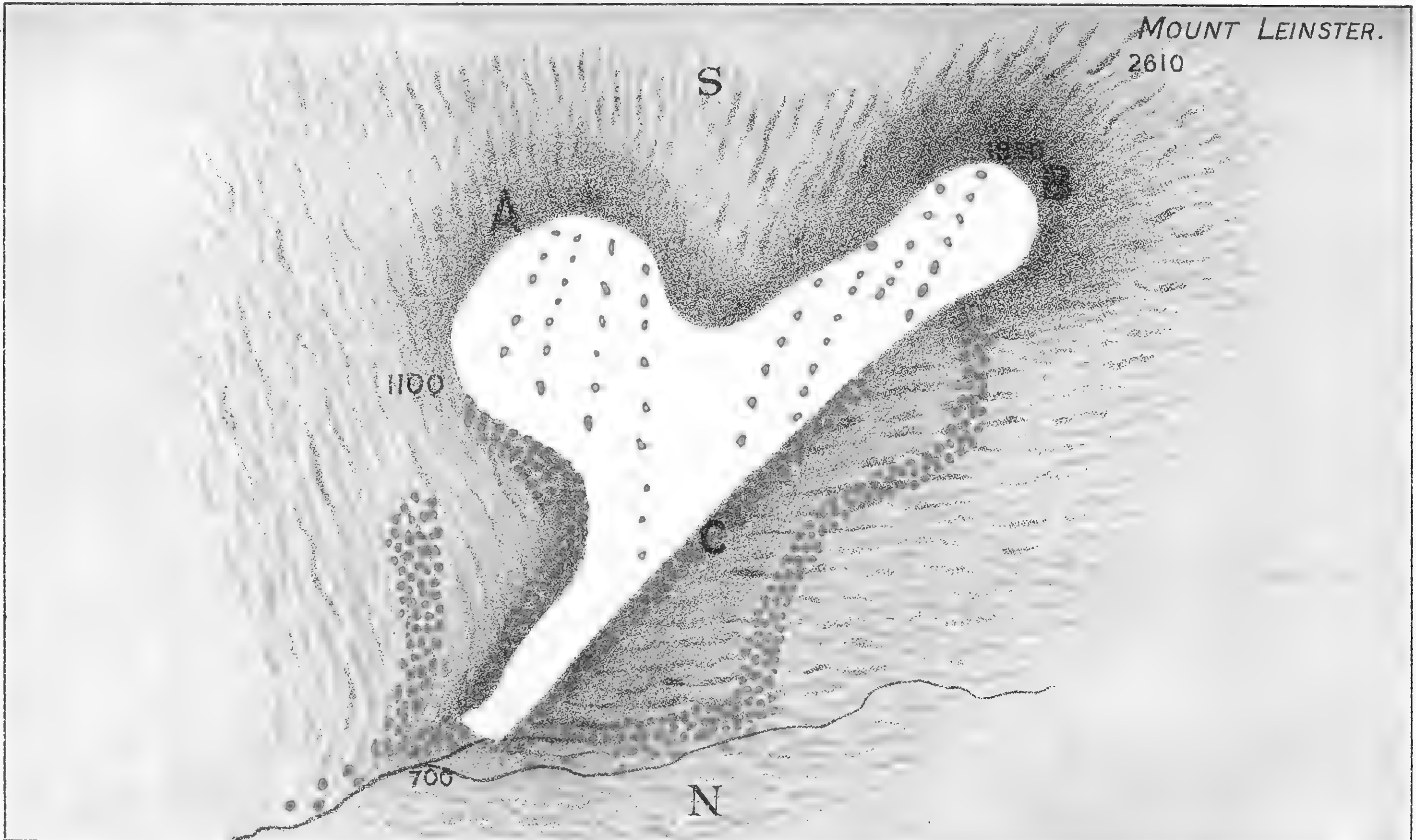
CRAAN COOM TO THE N.E. OF MT. LEINSTER WITH ITS RECORDS OF A CORRY GLACIER.

AS SEEN FROM THE NORTH NORTH EAST



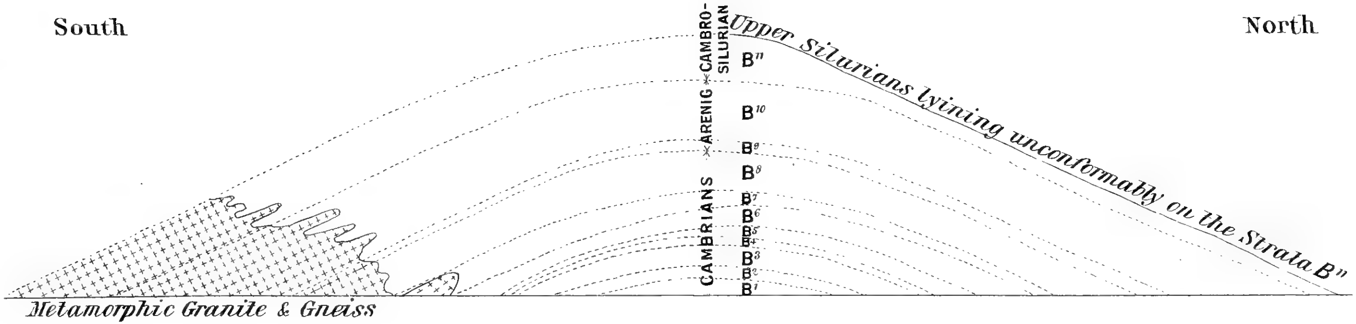
FORSTER & CO. LITH DUBLIN

MAP OF THE ANCIENT CORRY GLACIER MT LEINSTER

Scale 3½ Inches to One Mile.

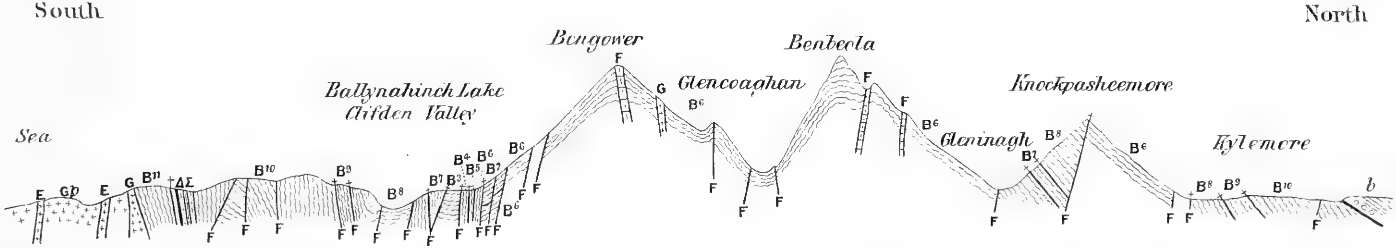
FORSTER & Co. LITH DUBLIN Harriette A. Kinahan

WALL FROM 20 TO 40 FEET HIGH ON THE N.W. OF THE SMALLER GLACIER, KILBRANNISH, CO. CARLOW.
AT C ON PLATE XXVIII.
(WINTER.)



Diagrammatic Section showing the relative position of the Groups of Strata on the North and South sides of the Great Anticlinal Curve–Bennabeola Mts Co Galway.

Forster & Co Lith, Dublin.



Section across (from South to North) the Bennabeola Mountains showing the actual position of the Groups of Strata.

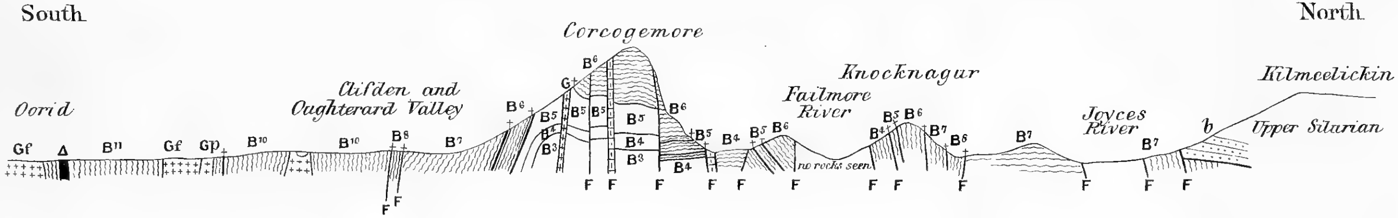
Horizontal Scale 1 Mile to 1 Inch   Vertical Scale 1 Mile to 3 inches.

INDEX.

B^1 Lower micalite series.
B^2 Streamstown limestone series.
B^3 Quartzitic micalite series.
B^4 Ophiolite and dolomite series.
B^5 Small micalite series.
B^6 Great quartzite series.
B^7 Middle micalite series.
B^8 Kylemore or Ballynahinch series.
B^9 Lettemore or small quartzite series.
B^{10} Great micalite series.
B^{11} Hornblendite & talcite series, or Doolough beds.

G. Intrusive granite.
Gp. Porphyritic granite (hornblendic).
Gf. Foliated granite or granitic gneiss.
E. Elvan.
F. Faults and dykes fault-rock.
b. Upper Silurian.
Δ. Hornblende-rock.
Σ. Ophite.

Forster & Co. Lith, Dublin.



South and North Section across the Corcogemore Hills, showing the actual position of the groups of Strata.

Horizontal Scale 1 Mile to 1 Inch Vertical Scale 1 Mile to 3 inches.

INDEX.

B[1] Lower micalite series.
B[2] Streamstown limestone series.
B[3] Quartzitic micalite series.
B[4] Ophiolite and dolomite series.
B[5] Small micalite series.
B[6] Great quartzite series.
B[7] Middle micalite series.
B[8] Kylemore or Ballynahinch series.
B[9] Lettemore or small quartzite series.
B[10] Great micalite series.
B[11] Hornblendite & talcite series or Doolough beds.

G. Intrusive granite.
Gp. Porphyritic granite (hornblendic)
Gf. Foliated granite or granitic-gneiss.
E. Elvan.
F. Faults and dykes fault-rock.
b. Upper Silurian.
Δ. Hornblende-rock.
Σ. Ophite.

Forster & C[o] Lith, Dublin.

Fig. 1

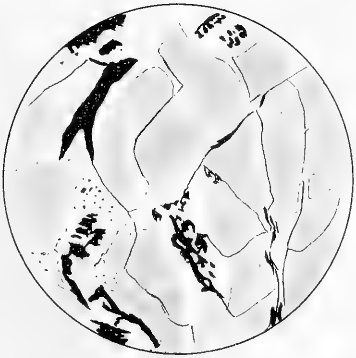


Fig. 2

Fig. 3

Fig. 4

SERPENTINE AND TREMOLITE.

FORSTER & Co. LITH, DUBLIN.